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Multichannel Sound Recording using 3,4 and 5 channel arrays for Front Sound Stage Coverage

Michael Williams, "Sounds of Scotland", Paris, France

soundsscot@aol.com

ABSTRACT

In previous papers the Multichannel Microphone Array Design (MMAD) procedure has been used mainly to determine the design of arrays giving complete 360° coverage of the sound field. Many sound recording engineers however use the main microphone array to cover only the front sound stage, and add in early reflections and reverberation either by artificial means (electronic generation) or by using a second array in the reverberation field. This paper describes MMAD procedure applied to only front coverage of the main sound stage using 3,4 or 5 channels-microphones, covering any desired angle within the front hemisphere, and for the usual 1st order microphone directivities. Various array alignments are described in the form of the arc-of-a-circle with different radius. All arrays described are critically linked (seamless) within the front hemisphere.

1. INTRODUCTION

For a multitude of reasons, the acoustic environment of many multichannel sound recording situations may not allow the sound recording engineer to use an array with complete 360° surround sound coverage. Added to this, the opening gambit for setting up the recording system very often excludes this approach in favour of splitting the coverage of the main sound stage from the generation of the early reflection and reverberation field. In this case two arrays are often used, one to cover the main sound stage, the other for the early reflection and reverberant field, the later on occasions being replaced by the electronic generation of an acoustical environment.

The actual number of channels and the corresponding loudspeaker configuration that will eventually give a completely satisfactory sound image either for the audio/visual media or the purely sound reproduction media is still to some extent uncertain. The five channel configuration is the present standard, but even within these five channels, we already find many different opinions as to how to configure the microphone array to cover different parts of the sound stage. A few array

systems only use 3 microphones (covering two front segments) to record the main sound stage, with either additional microphones or a second array to cover the reverberant field. On the other hand some sound engineers prefer coverage with a five microphone array in order to extend the reproduced sound stage of the front two segments into the lateral segments, whilst ignoring the very poor reproduction possibilities of the back segment. Whereas quite a few sound effects or ambiance tracks for the multichannel audio/visual media already use four channels, leaving the centre channel for commentary or specific synchronous in-screen sound effects. This must be contrasted with the surround sound enthusiasts who are looking for complete surround coverage coupled with perfect critical linking between all segments.

Up to now the Multichannel Microphone Array Design process has concentrated on arrays that satisfy complete surround sound coverage. This paper extends the design technique to analyse the characteristics of arrays needed for covering just the front sound stage. Each array is specified by the segment coverage characteristics together with the coordinates and orientation of each microphone, and critical linking is maintained between the four front coverage segments.

1. The Basic Criteria for Array Design

The only coherent approach to array design is to use the physical response of the microphones coupled with the psychoacoustics of each listening configuration, an approach that has been developed under the title 'MMAD' or Multichannel Microphone Array Design^[1-6] and previously for stereophonic sound recording. It is essential to show how this process can be applied to all types of microphone array configurations, whether they be used for complete surround sound coverage or for partial sound stage coverage.

The choice of different configurations of microphone arrays, designed specifically for front sound stage coverage, is at present very limited. In order to make available the widest possible choice of array designs, this paper will present a selection of arrays with specific parameters chosen so that the sound recording engineer can select the optimum array for a specific sound recording environment using the following selection criteria :

- No of Channels – three, four or five channel coverage of the front sound stage
- Univalent microphone/channel transmission
- Sound stage coverage angles from a maximum of 270° to a minimum of 90°
- Different microphone alignment configurations from the almost in-line array, to microphones aligned along the arc of a circle, with the possibility to choose from a number of circle radii.
- Microphone arrays are presented for the usual 1st order directivity range – Omnidirectional, Hypocardioid, Cardioid and Supercardioid.
- All criteria are independent of each other and all arrays are critically linked (seamless) within the front hemisphere
- The rear segment covered by the back pair of microphones is neglected in favour of the optimum front coverage characteristic.

2. Presentation of Array Designs

As the number of possible microphone array designs is almost infinite, only a limited number can be shown in this paper. The usual tabular presentation of each configuration has been adopted followed by a selection of plan view diagrams to illustrate each table. Five Channel Microphone Arrays are shown in Tables A to D with each table corresponding to a different 1st order microphone directivity :

- Table A for Omnidirectional microphone arrays
- Table B for Hypocardioid microphone arrays
- Table C for Cardioid microphone arrays
- Table D for Supercardioid microphone arrays

Three channel arrays can be selected from this table by using only the front three microphones from each array.

Four Channel Microphone Arrays are designed to be reproduced only by the left and right front loudspeakers, and the left and right surround loudspeakers – the centre channel is left either vacant, or available for other sound sources such as dialogue, commentary or a spot microphone on a central sound source. Four Channel Microphone Arrays are shown in Tables E to H.

- Table E for Omnidirectional microphone arrays
- Table F for Hypocardioid microphone arrays
- Table G for Cardioid microphone arrays
- Table H for Supercardioid microphone arrays

Out of the 296 arrays specified by these tables, only 92 are represented with a complete plan view. Each table contains a column giving the figure number of the corresponding plan view for the particular array.

In order to simplify the choice of possible arrays, none of the arrays shown in this tabular presentation need either microphone position offset, or electronic time or intensity offset to achieve critical linking. This means that the orientation of each microphone corresponds to the limit of the respective segment coverage.

3. Sound Stage Coverage

Figures 1, 2 and 3 (reproduced from the 24th International Conference presentation by the author) show the relationship between the front and lateral segment coverage, and the resulting loudspeaker reproduction.

The various Front and Lateral Segment Coverage values have been chosen so that the sound recording engineer can have the maximum flexibility in adjusting the proportion of the sound stage reproduced by the lateral segments in relation to the front segments, within the standard loudspeaker configuration for five channel reproduction. It remains to be seen whether the lateral segment coverage must be limited to the extremities of the sound stage, or opened up to include the natural early lateral reflection sound field.

The use of a front coverage array, together with a second microphone array in the reverberant field, will certainly enable the sound engineer to easily balance direct to reverberant sound, but natural early lateral reflections can usually only be picked up by the main microphone array - the only other solution being the use of electronic generation of both the reverberant and the early reflection sound field

The back segment is shown in the plan view diagrams for information only. In a Front Coverage array the pick-up of energy in the back segment will be negligible with respect to the direct sound in the front segments.

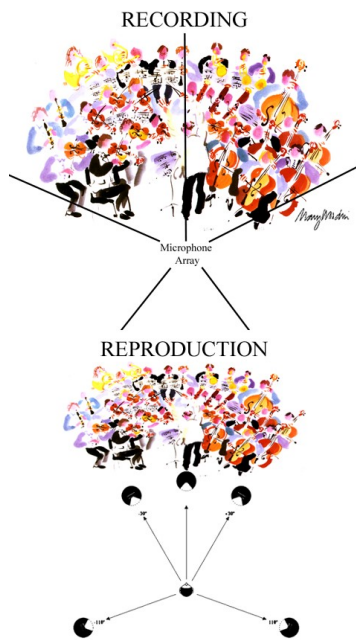


Figure 1 –The Front Segment Coverage is aligned with the extremities of the sound source

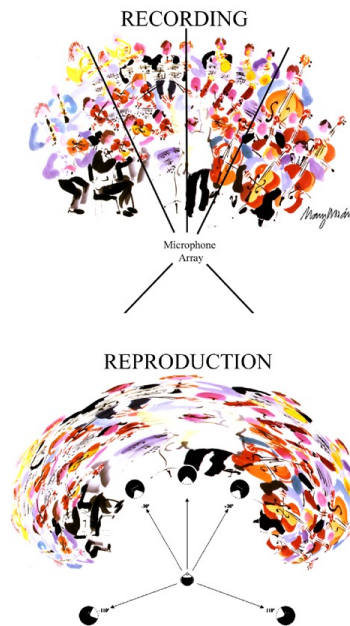


Figure 3 –The Front Segment Coverage is well within the sound source - reproduction is equally divided between the Front and Lateral Segments.

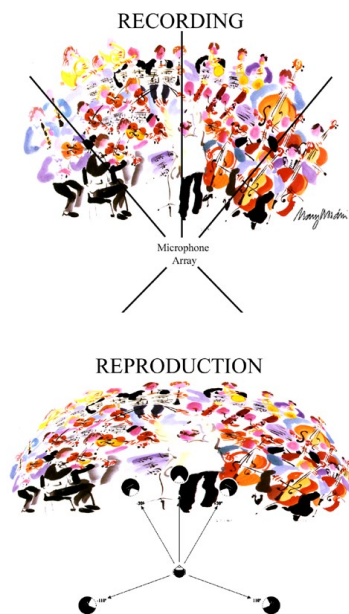


Figure 2 – The Front Segment Coverage is just within the sound source - reproduction is spread into the Lateral Segments

The concept of microphone position offset and electronic offset has been described in previous papers and can be used to continue the design of arrays with critical linking. These offset functions can be introduced so as to allow considerable freedom in the geometrical microphone array alignment. Linear alignment can be achieved to some cases with only microphone position offset, but the use of electronic offset will extent the range of possible configurations with critical linking.

Electronic offset can either be time delay based or intensity level based or a combination of both. The electronic time offset has the advantage of maintaining equal energy distribution throughout the array, whereas some sound engineers already adapt to psychoacoustic considerations by intuitively using a certain quantity of intensity offset to bring down the energy level in the centre of the microphone array sound stage. A balance must be observed between these two offset functions in order to achieve both critical linking and maintain a modicum of control over energy distribution throughout the microphone array coverage.

The very much wider choice of arrays is possible using both microphone position offset and/or electronic offset, but cannot be shown in the AES paper format, however the CD-ROM media has sufficient capacity to show the multitude of designs that are possible. It is hoped that the presentation of this paper will be accompanied by a CD-ROM - an update to the present SOS MMAD CD-ROM pre-release 2.0 previously distributed at the 24th International Conference presentation. Additional copies can be obtained from the author at:

soundsscot@aol.com.

REFERENCES :

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Note : I would like to thank the British artist Mary Woodin for permission to use her painting entitled "Orchestra" in order to illustrate part of the process of multichannel sound recording. I apologize for the sometimes considerable geometric distortion of her original painting, which has been introduced into some of the diagrams in order to illustrate certain aspects of this paper. This distortion is obviously not part of her original work. This and other paintings are published under the name of "Performance Cards".

Table A - FIVE Channel Front Coverage Arrays using OMNIDIRECTIONNAL Microphone

TABLE A		FIVE Channel Front Coverage Arrays using OMNIDIRECTIONNAL Microphones								
Front Segment Coverage	Lateral Segment Coverage	Centre front facing microphone is at coordinate (0,0)								Preprint Figure No
		LEFT SURROUND		LEFT		RIGHT		RIGHT SURROUND		
		X Coord	Y Coord	X Coord	Y Coord	X Coord	Y Coord	X Coord	Y Coord	
70°	70°	-36,4cm	-100,1cm	-53,2cm	-37,3cm	53,2cm	-37,3cm	36,4cm	-100,1cm	4
	60°	-40,2cm	-111,1cm					40,2cm	-111,1cm	
	50°	-45,6cm	-124,9cm					45,6cm	-124,9cm	5
	40°	-53,3cm	-145,3cm					53,3cm	-145,3cm	
	30°	-65,8cm	-180,7cm					65,8cm	-180,7cm	6
60°	70°	-59,3cm	-102,3cm	-65cm	-37,5cm	65cm	-37,5cm	59,3cm	-102,3cm	7
	60°	-65cm	-112,5cm					65cm	-112,5cm	
	50°	-72,7cm	-126,2cm					72,7cm	-126,2cm	8
	40°	-83,6cm	-142,9cm					83,6cm	-142,9cm	
	30°	-102,8cm	-178,5cm					102,8cm	-178,5cm	9
50°	70°	-86,4cm	-102,4cm	-80,7cm	-37,6cm	80,7cm	-37,6cm	86,4cm	-102,4cm	10
	60°	-93,7cm	-111,5cm					93,7cm	-111,5cm	
	50°	-103,7cm	-123,6cm					103,7cm	-123,6cm	11
	40°	-117,3cm	-138,2cm					117,3cm	-138,2cm	
	30°	-142,4cm	-169,9cm					142,4cm	-169,9cm	12
40°	70°	-117,2cm	-99,4cm	-100,5cm	-36,7cm	100,5cm	-36,7cm	117,2cm	-99,4cm	13
	60°	-126,2cm	-107,1cm					126,2cm	-107,1cm	
	50°	-138,2cm	-117,3cm					138,2cm	-117,3cm	14
	40°	-154,1cm	-129,3cm					154,1cm	-129,3cm	
	30°	-184,3cm	-156,2cm					184,3cm	-156,2cm	15
30°	70°	-168,5cm	-96,7cm	-141cm	-37,8cm	141cm	-37,8cm	168,5cm	-96,7cm	16
	60°	-178,6cm	-102,7cm					178,6cm	-102,7cm	
	50°	-192,1cm	-110,7cm					192,1cm	-110,7cm	17
	40°	-207,8cm	-119,8cm					207,8cm	-119,8cm	
	30°	-244,3cm	-141cm					244,3cm	-141cm	18

Table B - FIVE Channel Front Coverage Arrays using HYPOCARDIOID Microphones

TABLE B		FIVE Channel Front Coverage Arrays using HYPOCARDIOID Microphones												
Front Segment Coverage	Lateral Segment Coverage	Centre front facing microphone is at coordinate (0,0) with 0° compass orientation												
		LEFT SURROUND			LEFT			RIGHT			RIGHT SURROUND			Preprint Figure No
		Orient	X Coord	Y Coord	Orient	X Coord	Y Coord	Orient	X Coord	Y Coord	Orient	X Coord	Y Coord	
70°	70°	220°	-27,5cm	-75,4cm	290°	-40,1cm	-28,1cm	70°	40,1cm	-28,1cm	140°	27,5cm	-75,4cm	
	60°	230°	-29,7cm	-87,2cm							130°	29,7cm	-87,2cm	
	50°	240°	-33,5cm	-103,8cm							120°	33,5cm	-103,8cm	20
	40°	250°	-40,2cm	-129,1cm							110°	40,2cm	-129,1cm	
	30°	260°	-52cm	-163,6cm							100°	52cm	-163,6cm	21
60°	70°	230°	-47,7cm	-78,8cm	300°	-52cm	-30cm	60°	52cm	-30cm	130°	47,7cm	-78,8cm	22
	60°	240°	-52cm	-90cm							120°	52cm	-90cm	
	50°	250°	-58,6cm	-105,7cm							110°	58,6cm	-105,7cm	23
	40°	260°	-69,5cm	-129,5cm							100°	69,5cm	-129,5cm	
	30°	270°	-87,2cm	-161,4cm							90°	87,2cm	-161,4cm	24
50°	70°	240°	-73,2cm	-8,9cm	310°	-68,9cm	-32,1cm	50°	68,9cm	-32,1cm	120°	73,2cm	-80,9cm	25
	60°	250°	-79,2cm	-91,2cm							110°	79,2cm	-91,2cm	
	50°	260°	-88,6cm	-105,2cm							100°	88,6cm	-105,2cm	26
	40°	270°	-103,4cm	-127cm							90°	103,4cm	-127cm	
	30°	280°	-126,4cm	-155,4cm							80°	126,4cm	-155,4cm	27
40°	70°	250°	-107,6cm	-81,9cm	320°	-94,9cm	-34,5cm	40°	94,9cm	-34,5cm	110°	107,6cm	-81,9cm	28
	60°	260°	-115,5cm	-90,9cm							100°	115,5cm	-90,9cm	
	50°	270°	-127,1cm	-103,4cm							90°	127,1cm	-103,4cm	29
	40°	280°	-145,4cm	-122cm							80°	145,4cm	-122cm	
	30°	290°	-172,9cm	-145,9cm							70°	172,9cm	-145,9cm	30
30°	70°	260°	-152,1cm	-79,6cm	330°	-131,4cm	-35,2cm	30°	131,4cm	-35,2cm	100°	152,1cm	-79,6cm	31
	60°	270°	-161,4cm	-87,6cm							90°	161,4cm	-87,6cm	
	50°	280°	-175cm	-97,5cm							80°	175cm	-97,5cm	32
	40°	290°	-196,3cm	-112,6cm							70°	196,3cm	-112,6cm	
	30°	300°	-227,6cm	-131,4cm							60°	227,6cm	-131,4cm	33

Table C - FIVE Channel Front Coverage Arrays using CARDIOID Microphones

TABLE C		FIVE Channel Front Coverage Arrays using CARDIOID Microphones												
Front Segment Coverage	Lateral Segment Coverage	Centre front facing microphone is at coordinate (0,0) with 0° compass orientation												Preprint Figure No
		LEFT SURROUND			LEFT			RIGHT			RIGHT SURROUND			
		Orient	X Coord	Y Coord	Orient	X Coord	Y Coord	Orient	X Coord	Y Coord	Orient	X Coord	Y Coord	
70°	70°	220°	-23cm	-63,1cm	290°	-33,6cm	-23,5cm	70°	33,6cm	-23,5cm	140°	23cm	-63,1cm	34
	60°	230°	-24,4cm	-75,7cm							130°	24,4cm	-75,7cm	
	50°	240°	-27,6cm	-92,3cm							120°	27,6cm	-92,3cm	35
	40°	250°	-33,6cm	-117,5cm							110°	33,6cm	-117,5cm	
	30°	260°	-44,9cm	-153cm							100°	44,9cm	-153cm	36
60°	70°	230°	-42,4cm	-67,3cm	300°	-45,9cm	-26,5cm	60°	45,9cm	-26,5cm	130°	42,4cm	-67,3cm	37
	60°	240°	-45,9cm	-79,5cm							120°	45,9cm	-79,5cm	
	50°	250°	-51,9cm	-95,2cm							110°	51,9cm	-95,2cm	38
	40°	260°	-62,2cm	-119,1cm							100°	62,2cm	-119,1cm	
	30°	270°	-79,6cm	-152,1cm							90°	79,6cm	-152,1cm	39
50°	70°	240°	-68,6cm	-97,9cm	310°	-62,5cm	-29,2cm	50°	62,5cm	-29,2cm	120°	68,6cm	-97,9cm	40
	60°	250°	-71,8cm	-81,4cm							110°	71,8cm	-81,4cm	
	50°	260°	-80,4cm	-98,8cm							100°	80,4cm	-95,8cm	41
	40°	270°	-94,7cm	-117,5cm							90°	94,7cm	-117,5cm	
	30°	280°	-117,5cm	-147cm							80°	117,5cm	-147cm	42
40°	70°	250°	-99cm	-71,8cm	320°	-88,3cm	-32,1cm	40°	88,3cm	-32,1cm	110°	99cm	-71,8cm	43
	60°	260°	-106,5cm	-82cm							100°	106,5cm	-82cm	
	50°	270°	-117,5cm	-94,7cm							90°	117,5cm	-94,7cm	44
	40°	280°	-135,4cm	-113,6cm							80°	135,4cm	-113,6cm	
	30°	290°	-162,9cm	-138,6cm							70°	162,9cm	-138,6cm	45
30°	70°	260°	-142,9cm	-70,8cm	330°	-125,6cm	-33,6cm	30°	125,6cm	-33,6cm	100°	142,9cm	-70,8cm	46
	60°	270°	-152,1cm	-79,5cm							90°	152,1cm	-79,5cm	
	50°	280°	-165,2cm	-90,2cm							80°	165,2cm	-90,2cm	47
	40°	290°	-186cm	-105,7cm							70°	186cm	-105,7cm	
	30°	300°	-217,5cm	-125,6cm							60°	217,5cm	-125,6cm	48

Table D - FIVE Channel Front Coverage Arrays using SUPERCARDIOID Microphones

TABLE D		FIVE Channel Front Coverage Arrays using SUPERCARDIOID Microphones												
Front Segment Coverage	Lateral Segment Coverage	Centre front facing microphone is at coordinate (0,0) with 0° compass orientation												
		LEFT SURROUND			LEFT			RIGHT			RIGHT SURROUND			Preprint Figure No
		Orient	X Coord	Y Coord	Orient	X Coord	Y Coord	Orient	X Coord	Y Coord	Orient	X Coord	Y Coord	
70°	70°	220°	-11,9cm	-82,9cm	290°	-28,7cm	-20,1cm	70°	28,7cm	-20,1cm	140°	19,6cm	-53,9cm	49
	60°	230°	-20,4cm	-67,3cm							130°	20,4cm	-67,3cm	
	50°	240°	-22,9cm	-85,8cm							120°	22,9cm	-85,8cm	50
	40°	250°	-28,7cm	-109,1cm							110°	28,7cm	-109,1cm	
	30°	260°	-39,9cm	-147,6cm							100°	39,9cm	-147,6cm	51
60°	70°	230°	-38,5cm	-58,9cm	300°	-41,6cm	-24cm	60°	41,6cm	-24cm	130°	38,5cm	-58,9cm	52
	60°	240°	-41,6cm	-72cm							120°	41,6cm	-72cm	
	50°	250°	-47,3cm	-89,7cm							110°	47,3cm	-89,7cm	53
	40°	260°	-57cm	-111,6cm							100°	57cm	-111,6cm	
	30°	270°	-74,7cm	-147,6cm							90°	74,7cm	-147,6cm	54
50°	70°	240°	-62,9cm	-62,8cm	310°	-59,8cm	-27,9cm	50°	59,8cm	-27,9cm	120°	62,9cm	-62,8cm	55
	60°	250°	-68,2cm	75,2cm							110°	68,2cm	75,2cm	
	50°	260°	-76,9cm	-91,6cm							100°	76,9cm	-91,6cm	56
	40°	270°	-90,3cm	-111,5cm							90°	90,3cm	-111,5cm	
	30°	280°	-113,9cm	-143,9cm							80°	113,9cm	-143,9cm	57
40°	70°	250°	-92,7cm	-64,2cm	320°	-83,6cm	-30,4cm	40°	83,6cm	-30,4cm	110°	92,7cm	-64,2cm	58
	60°	260°	-100,1cm	-75,5cm							100°	100,1cm	-75,5cm	
	50°	270°	-111,6cm	-90,3cm							90°	111,6cm	-90,3cm	59
	40°	280°	-128,2cm	-107,5cm							80°	128,2cm	-107,5cm	
	30°	290°	-157,1cm	-135,3cm							70°	157,1cm	-135,3cm	60
30°	70°	260°	-138,5cm	-64,8cm	330°	-115,9cm	-31,1cm	30°	115,9cm	-31,1cm	100°	138,5cm	-64,8cm	61
	60°	270°	-147,7cm	-74,7cm							90°	147,7cm	-74,7cm	
	50°	280°	-161,5cm	-87,2cm							80°	161,5cm	-87,2cm	62
	40°	290°	-180,9cm	-101,3cm							70°	180,9cm	-101,3cm	
	30°	300°	-214,2cm	-123,6cm							60°	214,2cm	-123,6cm	63

Table E – FOUR Channel Front Coverage Arrays using OMNIDIRECTIONAL Microphones

TABLE E		FOUR Channel Front Coverage Arrays using OMNIDIRECTIONAL Microphones								Preprint Figure No
Front Segment Coverage	Lateral Segment Coverage	NO CENTRE MICROPHONE								
		LEFT SURROUND		LEFT		RIGHT		RIGHT SURROUND		
		X coord	Ycoord	X coord	Ycoord	X coord	Ycoord	X coord	Ycoord	
90°	90°	-26,5cm	-53cm	-26,5cm	0 cm	26,5cm	0 cm	26,5cm	-53cm	64
	80°	-31,6cm	-58,8cm					31,6cm	-58,8cm	
	70°	-38cm	-65cm					38cm	-65cm	
	60°	-46,4cm	-74,4cm					46,4cm	-74,4cm	
	50°	-57,6cm	-85,5cm					57,6cm	-85,5cm	
	40°	-74,3cm	-102,4cm					74,3cm	-102,4cm	
	30°	-102,5cm	-131,6cm					102,5cm	-131,6cm	
80°	90°	-34,1cm	-52,8cm	-29,5cm	0 cm	29,5cm	0 cm	34,1cm	-52,8cm	66
	80°	-39,7cm	-58,1cm					39,7cm	-58,1cm	
	70°	-46,6cm	-63,8cm					46,6cm	-63,8cm	
	60°	-55,8cm	-72,4cm					55,8cm	-72,4cm	
	50°	-68cm	-82,5cm					68cm	-82,5cm	
	40°	-86cm	-97,9cm					86cm	-97,9cm	
	30°	-116,7cm	-124,5cm					116,7cm	-124,5cm	
70°	90°	-42,2cm	-52,2cm	-33cm	0 cm	33cm	0 cm	42,2cm	-52,2cm	68
	80°	-48,3cm	-57cm					48,3cm	-57cm	
	70°	-55,6cm	-62cm					55,6cm	-62cm	
	60°	-65,5cm	-69,8cm					65,5cm	-69,8cm	
	50°	-78,5cm	-78,8cm					78,5cm	-78,8cm	
	40°	-97,8cm	-92,6cm					97,8cm	-92,6cm	
	30°	-130,7cm	-116,4cm					130,7cm	-116,4cm	
60°	90°	-52,2cm	-51,2cm	-38,5cm	0 cm	38,5cm	0 cm	52,2cm	-51,2cm	70
	80°	-58,7cm	-55,4cm					58,7cm	-55,4cm	
	70°	-66,4cm	-59,8cm					66,4cm	-59,8cm	
	60°	-77cm	-66,7cm					77cm	-66,7cm	
	50°	-90,7cm	-74,5cm					90,7cm	-74,5cm	
	40°	-111,1cm	-86,6cm					111,1cm	-86,6cm	
	30°	-146cm	-107,5cm					146cm	-107,5cm	
50°	90°	-63,6cm	-49,8cm	-45,5cm	0 cm	45,5cm	0 cm	63,6cm	-49,8cm	72
	80°	-70,4cm	-53,5cm					70,4cm	-53,5cm	
	70°	-78,5cm	-57,2cm					78,5cm	-57,2cm	
	60°	-89,7cm	-63,1cm					89,7cm	-63,1cm	
	50°	-104cm	-69,7cm					104cm	-69,7cm	
	40°	-125,4cm	-79,9cm					125,4cm	-79,9cm	
	30°	-161,9cm	-97,7cm					161,9cm	-97,7cm	
40°	90°	-78,9cm	-48cm	-56,5cm	0 cm	56,5cm	0 cm	78,9cm	-48cm	74
	80°	-86cm	-51,1cm					86cm	-51,1cm	
	70°	-94,4cm	-54,1cm					94,4cm	-54,1cm	
	60°	-106cm	-59cm					106cm	-59cm	
	50°	-120,8cm	-64,3cm					120,8cm	-64,3cm	
	40°	-143,1cm	-72,6cm					143,1cm	-72,6cm	
	30°	-181cm	-87,2cm					181cm	-87,2cm	
30°	90°	-102,5cm	-45,9cm	-76cm	0 cm	76cm	0 cm	102,5cm	-45,9cm	76
	80°	-109,8cm	-48,3cm					109,8cm	-48,3cm	
	70°	-118,4cm	-50,6cm					118,4cm	-50,6cm	
	60°	-130,4cm	-54,4cm					130,4cm	-54,4cm	
	50°	-145,7cm	-58,5cm					145,7cm	-58,5cm	
	40°	-168,6cm	-64,8cm					168,6cm	-64,8cm	
	30°	-207,6cm	-76cm					207,6cm	-76cm	

Table F – FOUR Channel Front Coverage Arrays using HYPOCARDIOID Microphones

Table F		FOUR Channel Front Coverage Arrays using HYPOCARDIOID Microphones												Figure No
Front Segment Coverage	Lateral Segment Coverage	LEFT SURROUND			LEFT			RIGHT			RIGHT SURROUND			
		Orient	X Coord	Y Coord	Orient	X Coord	Y Coord	Orient	X Coord	Y Coord	Orient	X Coord	Y Coord	
90°	90°	225°	-17cm	-34cm	315°	-17cm	0 cm	45°	17cm	0 cm	135°	17cm	-34cm	72
	80°	235°	-20,6cm	-40,8cm							125°	20,6cm	-40,8cm	
	70°	245°	-25,7cm	-49,2cm							115°	25,7cm	-49,2cm	
	60°	255°	-33cm	-59,9cm							105°	33cm	-59,9cm	
	50°	265°	-44cm	-74,2cm							95°	44cm	-74,2cm	
	40°	275°	-61,4cm	-95,2cm							85°	61,4cm	-95,2cm	
	30°	285°	-90cm	-126,4cm							75°	90cm	-126,4cm	
80°	90°	230°	-23,5cm	-33,9cm	320°	-20,5cm	0 cm	40°	20,5cm	0 cm	130°	23,5cm	-33,9cm	73
	80°	240°	-27,6cm	-40,4cm							120°	27,6cm	-40,4cm	
	70°	250°	-35cm	-54,1cm							110°	35cm	-54,1cm	
	60°	260°	-41,7cm	-58,3cm							100°	41,7cm	-58,3cm	
	50°	270°	-53,9cm	-71,6cm							90°	53,9cm	-71,6cm	
	40°	280°	-73cm	-90,9cm							80°	73cm	-90,9cm	
	30°	290°	-104,2cm	-119,6cm							70°	104,2cm	-119,6cm	
70°	90°	235°	-30,9cm	-33,5cm	325°	-25cm	0 cm	35°	25cm	0 cm	125°	30,9cm	-33,5cm	74
	80°	245°	-35,6cm	-39,6cm							115°	35,6cm	-39,6cm	
	70°	255°	-42,1cm	-47cm							105°	42,1cm	-47cm	
	60°	265°	-51,2cm	-56,2cm							95°	51,2cm	-56,2cm	
	50°	275°	-64,5cm	-68,4cm							85°	64,5cm	-68,4cm	
	40°	285°	-85,2cm	-86cm							75°	85,2cm	-86cm	
	30°	295°	-118,2cm	-111,8cm							65°	118,2cm	-111,8cm	
60°	90°	240°	-39,8cm	-32,8cm	330°	-31cm	0 cm	30°	31cm	0 cm	120°	39,8cm	-32,8cm	75
	80°	250°	45cm	-38,5cm							110°	45cm	-38,5cm	
	70°	260°	-52,1cm	-45,3cm							100°	52,1cm	-45,3cm	
	60°	270°	-62cm	-53,7cm							90°	62cm	-53,7cm	
	50°	280°	-76,3cm	-64,7cm							80°	76,3cm	-64,7cm	
	40°	290°	-98,5cm	-80,4cm							70°	98,5cm	-80,4cm	
	30°	300°	-134,2cm	-103,2cm							60°	134,2cm	-103,2cm	
50°	90°	245°	-51,1cm	-31,9cm	335°	-39,5cm	0 cm	25°	39,5cm	0 cm	115°	51,1cm	-31,9cm	76
	80°	255°	-56,8cm	-37,2cm							105°	56,8cm	-37,2cm	
	70°	265°	-64,5cm	-43,3cm							95°	64,5cm	-43,3cm	
	60°	275°	-75,1cm	-50,8cm							85°	75,1cm	-50,8cm	
	50°	285°	-90,3cm	-60,5cm							75°	90,3cm	-60,5cm	
	40°	295°	-113,7cm	-74,2cm							65°	113,7cm	-74,2cm	
	30°	305°	-151,3cm	-93,8cm							55°	151,3cm	-93,8cm	
40°	90°	250°	-66,9cm	-30,8cm	340°	-52,5cm	0 cm	20°	52,5cm	0 cm	110°	66,9cm	-30,8cm	77
	80°	260°	-73cm	-35,5cm							100°	73cm	-35,5cm	
	70°	270°	-81,2cm	-41cm							90°	81,2cm	-41cm	
	60°	280°	-92,4cm	-47,5cm							80°	92,4cm	-47,5cm	
	50°	290°	-108,4cm	-55,9cm							70°	108,4cm	-55,9cm	
	40°	300°	-132,9cm	-67,5cm							60°	132,9cm	-67,5cm	
	30°	310°	-172,1cm	-83,7cm							50°	172,1cm	-83,7cm	
30°	90°	255°	-90cm	-29,4cm	345°	-73cm	0 cm	15°	73cm	0 cm	105°	90cm	-29,4cm	78
	80°	265°	-96,5cm	-33,6cm							95°	96,5cm	-33,6cm	
	70°	275°	-105,1cm	-38,3cm							85°	105,1cm	-38,3cm	
	60°	285°	-116,8cm	-43,8cm							75°	116,8cm	-43,8cm	
	50°	295°	-133,5cm	-50,8cm							65°	133,5cm	-50,8cm	
	40°	305°	-159cm	-60,2cm							55°	159cm	-60,2cm	
	30°	315°	-199,4cm	-73cm							45°	199,4cm	-73cm	

Table G – FOUR Channel Front Coverage Arrays using CARDIOID Microphones

Table G		FOUR Channel Front Coverage Arrays using CARDIOID Microphones												Preprint Figure No	
Front Segment Coverage	Lateral Segment Coverage	LEFT SURROUND			LEFT			RIGHT			RIGHT SURROUND				
		Orient	X Coord	Y Coord	Orient	X Coord	Y Coord	Orient	X Coord	Y Coord	Orient	X Coord	Y Coord		
90°	90°	225°	12,5cm	-25cm	315°	-12,5cm	0 cm	45°	12,5cm	0 cm	135°	12,5cm	-25cm	80	
	80°	235°	15,3cm	-31,9cm							125°	15,3cm	-32,9cm		
	70°	245°	19,8cm	-41,4cm							115°	19,8cm	-41,4cm		
	60°	255°	27cm	-54,1cm							105°	27cm	-54,1cm		
	50°	265°	37,8cm	-69,5cm							95°	37,8cm	-69,5cm		
	40°	275°	53,9cm	-88,8cm							85°	53,9cm	-88,8cm		81
	30°	285°	72,5cm	-103,9cm							75°	72,5cm	-103,9cm		
80°	90°	230°	-18,7cm	-24,9cm	320°	-16,5cm	0 cm	40°	16,5cm	0 cm	130°	18,7cm	-24,9cm	82	
	80°	240°	-22,1cm	-31,5cm							120°	22,1cm	-31,5cm		
	70°	250°	-27,4cm	-40,6cm							110°	27,4cm	-40,6cm		
	60°	260°	-35,7cm	-52,6cm							100°	35,7cm	-52,6cm		
	50°	270°	-47,8cm	-67,1cm							90°	47,8cm	-67,1cm		
	40°	280°	-55,5cm	-67,5cm							80°	55,5cm	-67,5cm		
	30°	290°	-85,3cm	-98,3cm							70°	85,3cm	-98,3cm		
70°	90°	235°	-25,3cm	-24,6cm	325°	-21cm	0 cm	35°	21cm	0 cm	125°	25,3cm	-24,6cm	83	
	80°	245°	-29,5cm	-31,9cm							115°	29,5cm	-31,9cm		
	70°	255°	-35,4cm	-39,5cm							105°	35,4cm	-39,5cm		
	60°	265°	-44,7cm	-50,8cm							95°	44,7cm	-50,8cm		
	50°	275°	-58cm	-85cm							85°	58cm	-85cm		
	40°	285°	-77,2cm	-80,3cm							75°	77,2cm	-80,3cm		
	30°	295°	-98,1cm	-91,9cm							65°	98,1cm	-91,9cm		
60°	90°	240°	34,5cm	-24,1cm	330°	-28cm	0 cm	30°	28cm	0 cm	120°	34,5cm	-24,1cm	84	
	80°	250°	39,3cm	-31cm							110°	39,3cm	-31cm		
	70°	260°	45,7cm	-38,1cm							100°	45,7cm	-38,1cm		
	60°	270°	56cm	-48,5cm							90°	56cm	-48,5cm		
	50°	280°	70,4cm	-60,6cm							80°	70,4cm	-60,6cm		
	40°	290°	91cm	-75,1cm							70°	91cm	-75,1cm		
	30°	300°	112,9cm	84,9cm							60°	112,9cm	84,9cm		
50°	90°	245°	-45,6cm	-23,5cm	335°	-37cm	0 cm	25°	37cm	0 cm	115°	45,6cm	-23,5cm	85	
	80°	255°	-50,9cm	-29,9cm							105°	50,9cm	-29,9cm		
	70°	265°	-58cm	-36,4cm							95°	58cm	-36,4cm		
	60°	275°	-69,1cm	-45,9cm							85°	69,1cm	-45,9cm		
	50°	285°	-84,6cm	-56,7cm							75°	84,6cm	-56,7cm		
	40°	295°	-106,3cm	-69,3cm							65°	106,3cm	-69,3cm		
	30°	305°	-128,7cm	-77,1cm							55°	128,7cm	-77,1cm		
40°	90°	250°	-59,6cm	-22,7cm	340°	-49cm	0 cm	20°	49cm	0 cm	110°	59,6cm	-22,7cm	86	
	80°	260°	-65,5cm	-28,6cm							100°	65,5cm	-28,6cm		
	70°	270°	-73,1cm	-34,4cm							90°	73,1cm	-34,4cm		
	60°	280°	-85cm	-42,9cm							80°	85cm	-42,9cm		
	50°	290°	-101,3cm	-52,3cm							70°	101,3cm	-52,3cm		
	40°	300°	-124,1cm	-63cm							60°	124,1cm	-63cm		
	30°	310°	-147,3cm	-68,8cm							50°	147,3cm	-68,8cm		
30°	90°	255°	-72,5cm	-21,7cm	345°	-60cm	0 cm	73cm	60cm	0 cm	105°	72,5cm	-21,7cm	87	
	80°	265°	-78,9cm	-27cm							95°	78,9cm	-27cm		
	70°	275°	-87cm	-32,2cm							85°	87cm	-32,2cm		
	60°	285°	-99,6cm	-39,6cm							75°	99,6cm	-39,6cm		
	50°	295°	-116,7cm	-47,6cm							65°	116,7cm	-47,6cm		
	40°	305°	-140,3cm	-56,2cm							55°	140,3cm	-56,2cm		
	30°	315°	-163,9cm	-60cm							45°	163,9cm	-60cm		

Table H – FOUR Channel Front Coverage Arrays using SUPERCARDIOID Microphones

Table H		FOUR Channel Front Coverage Arrays using SUPERCARDIOID Microphones												Figure No
Front Segment Coverage	Lateral Segment Coverage	LEFT SURROUND			LEFT			RIGHT			RIGHT SURROUND			
		Orient	X Coord	Y Coord	Orient	X Coord	Y Coord	Orient	X Coord	Y Coord	Orient	X Coord	Y Coord	
90°	90°	225°	-8,2cm	-16,4cm	315°	-8,2cm	0 cm	45°	8,2cm	0 cm	135°	8,2cm	-16,4cm	88
	80°	235°	-10,5cm	-25,9cm							125°	10,5cm	-25,9cm	
	70°	245°	-14,6cm	-36,4cm							115°	14,6cm	-36,4cm	
	60°	255°	-21,1cm	-48,3cm							105°	21,1cm	-48,3cm	
	50°	265°	-31,5cm	-63,9cm							95°	31,5cm	-63,9cm	
	40°	275°	-48,8cm	-87cm							85°	48,8cm	-87cm	
	30°	285°	-77,2cm	-119,5cm							75°	77,2cm	-119,5cm	
80°	90°	230°	-14,4cm	-16,3cm	320°	-13cm	0 cm	40°	13cm	0 cm	130°	14,4cm	-16,3cm	90
	80°	240°	-17,5cm	-25,6cm							120°	17,5cm	-25,6cm	
	70°	250°	-22,6cm	-35,7cm							110°	22,6cm	-35,7cm	
	60°	260°	-30,1cm	-47cm							100°	30,1cm	-47cm	
	50°	270°	-41,7cm	-61,6cm							90°	41,7cm	-61,6cm	
	40°	280°	-61cm	-83,1cm							80°	61cm	-83,1cm	
	30°	290°	-92,2cm	-113cm							70°	92,2cm	-113cm	
70°	90°	235°	-21,3cm	-16,2cm	325°	-18,5cm	0 cm	35°	18,5cm	0 cm	125°	21,3cm	-16,2cm	92
	80°	245°	-25,2cm	-25,1cm							115°	25,2cm	-25,1cm	
	70°	255°	-31,2cm	-34,8cm							105°	31,2cm	-34,8cm	
	60°	265°	-39,6cm	-45,3cm							95°	39,6cm	-45,3cm	
	50°	275°	-52,5cm	-58,9cm							85°	52,5cm	-58,9cm	
	40°	285°	-73,6cm	-78,6cm							75°	73,6cm	-78,6cm	
	30°	295°	-107,2cm	-105,7cm							65°	107,2cm	-105,7cm	
60°	90°	240°	-29,2cm	-15,8cm	330°	-25cm	0 cm	30°	25cm	0 cm	120°	29,2cm	-15,8cm	94
	80°	250°	-33,9cm	-24,4cm							110°	33,9cm	-24,4cm	
	70°	260°	-40,6cm	-33,5cm							100°	40,6cm	-33,5cm	
	60°	270°	-50cm	-43,3cm							90°	50cm	-43,3cm	
	50°	280°	-64cm	-55,7cm							80°	64cm	-55,7cm	
	40°	290°	-86,7cm	-73,5cm							70°	86,7cm	-73,5cm	
	30°	300°	-122,6cm	-97,6cm							60°	122,6cm	-97,6cm	
50°	90°	245°	-39,6cm	-15,4cm	335°	-34cm	0 cm	25°	34cm	0 cm	115°	39,6cm	-15,4cm	96
	80°	255°	-45cm	-23,6cm							105°	45cm	-23,6cm	
	70°	265°	-52,5cm	-32cm							95°	52,5cm	-32cm	
	60°	275°	-62,7cm	-41cm							85°	62,7cm	-41cm	
	50°	285°	-77,7cm	-52,1cm							75°	77,7cm	-52,1cm	
	40°	295°	-101,9cm	-67,9cm							65°	101,9cm	-67,9cm	
	30°	305°	-139,7cm	-88,7cm							55°	139,7cm	-88,7cm	
40°	90°	250°	-54,9cm	-14,9cm	340°	-48cm	0 cm	20°	48cm	0 cm	110°	54,9cm	-14,9cm	98
	80°	260°	-61cm	-22,5cm							100°	61cm	-22,5cm	
	70°	270°	-69,2cm	-30,3cm							90°	69,2cm	-30,3cm	
	60°	280°	-80,1cm	-38,3cm							80°	80,1cm	-38,3cm	
	50°	290°	-96,1cm	-48,1cm							70°	96,1cm	-48,1cm	
	40°	300°	-121,5cm	-61,7cm							60°	121,5cm	-61,7cm	
	30°	310°	-161cm	-79,2cm							50°	161cm	-79,2cm	
30°	90°	255°	-77,2cm	-14,2cm	345°	-69cm	0 cm	73cm	69cm	0 cm	105°	77,2cm	-14,2cm	100
	80°	265°	-83,9cm	-21,3cm							95°	83,9cm	-21,3cm	
	70°	275°	-92,8cm	-28,3cm							85°	92,8cm	-28,3cm	
	60°	285°	-104,4cm	-35,4cm							75°	104,4cm	-35,4cm	
	50°	295°	-121,1cm	-43,7cm							65°	121,1cm	-43,7cm	
	40°	305°	-147,6cm	-55,1cm							55°	147,6cm	-55,1cm	
	30°	315°	-188,5cm	-69cm							45°	188,5cm	-69cm	

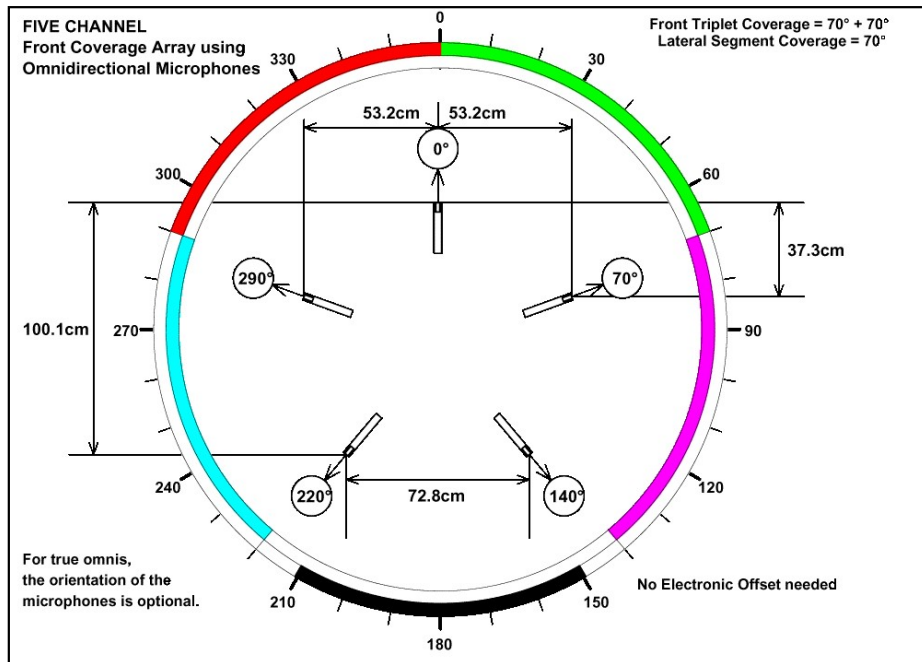


Figure 4

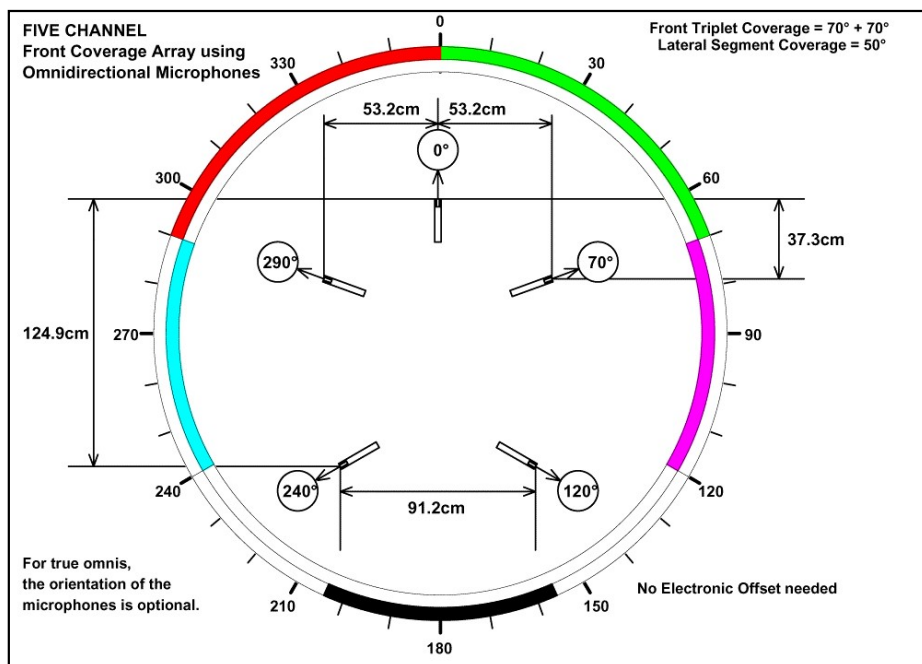


Figure 5

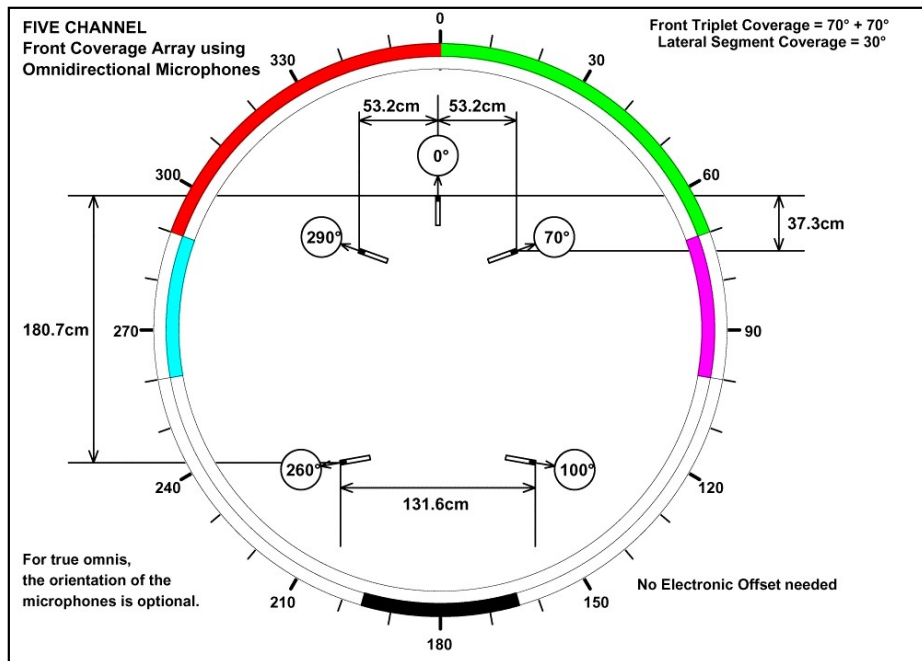


Figure 6

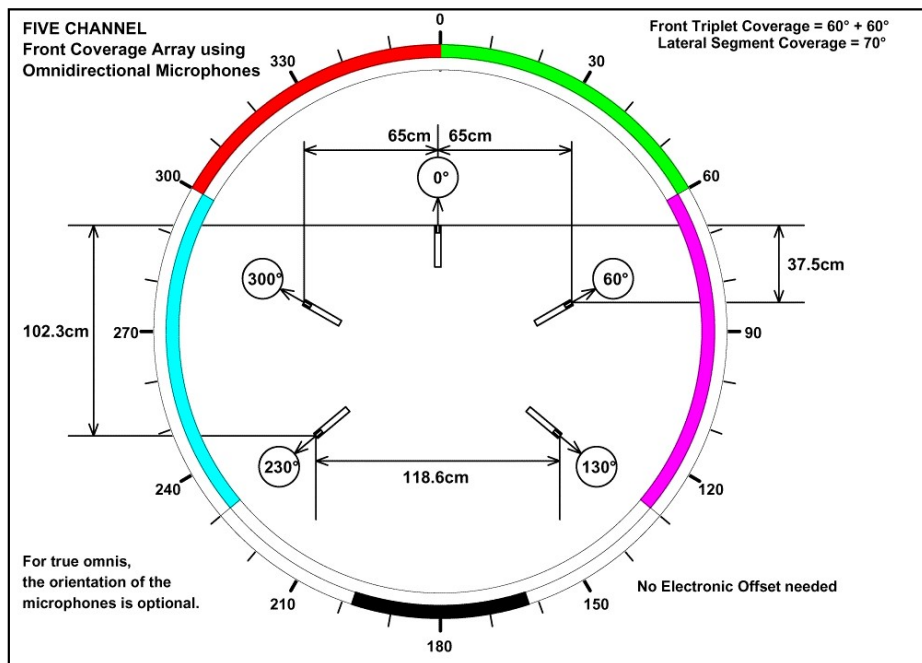


Figure 7

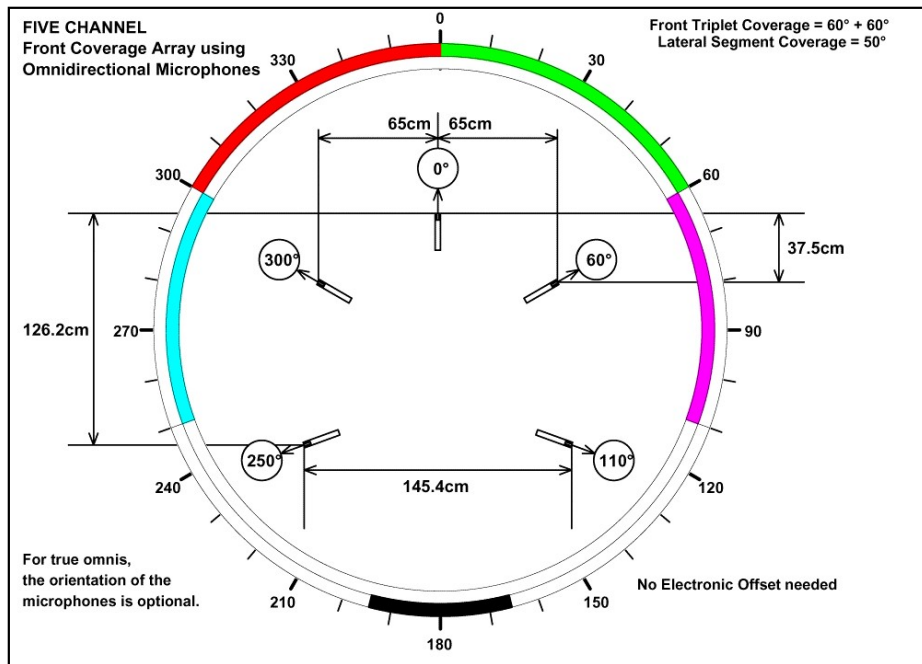


Figure 8

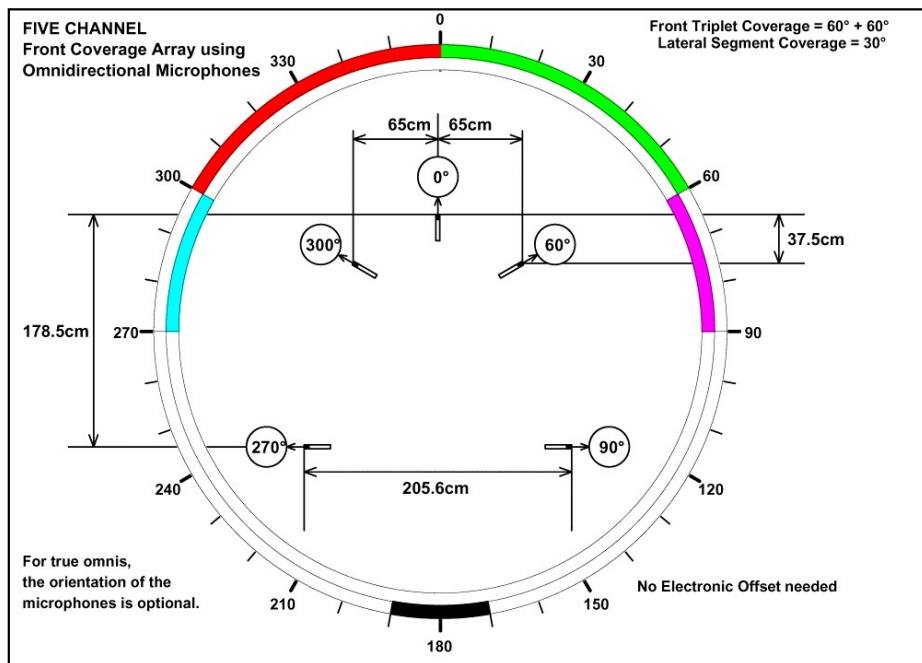


Figure 9

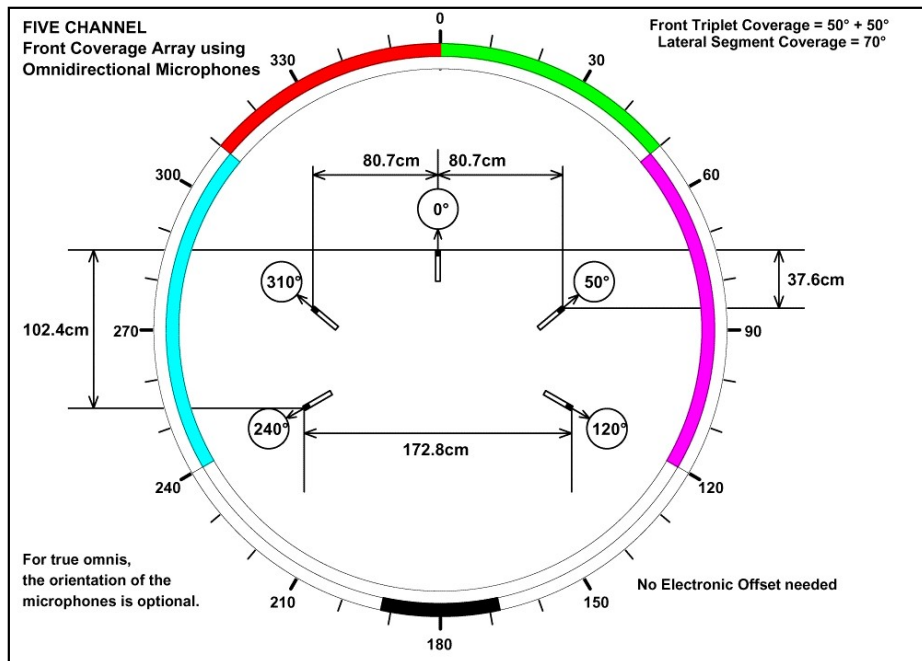


Figure 10

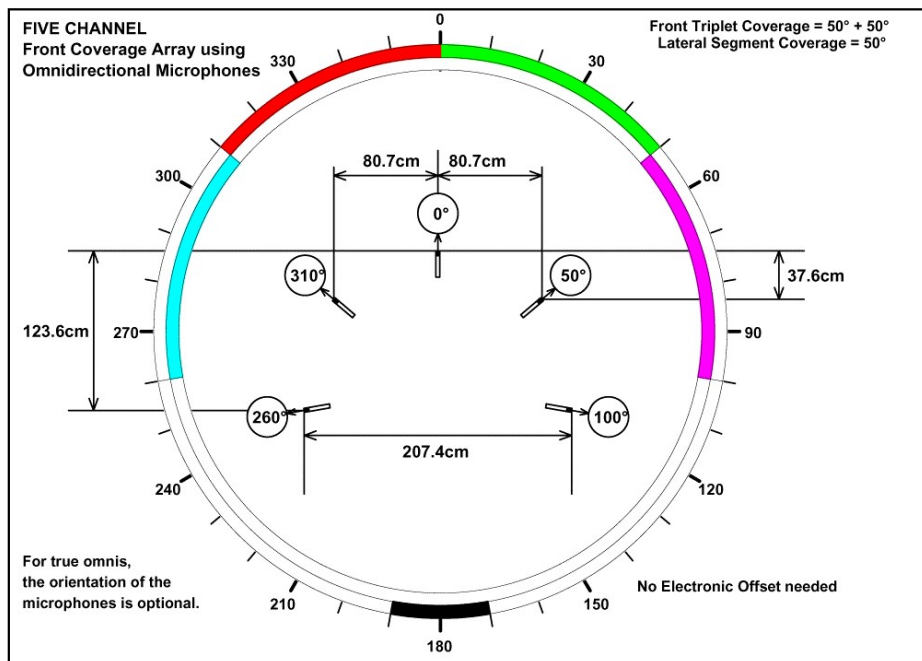


Figure 11

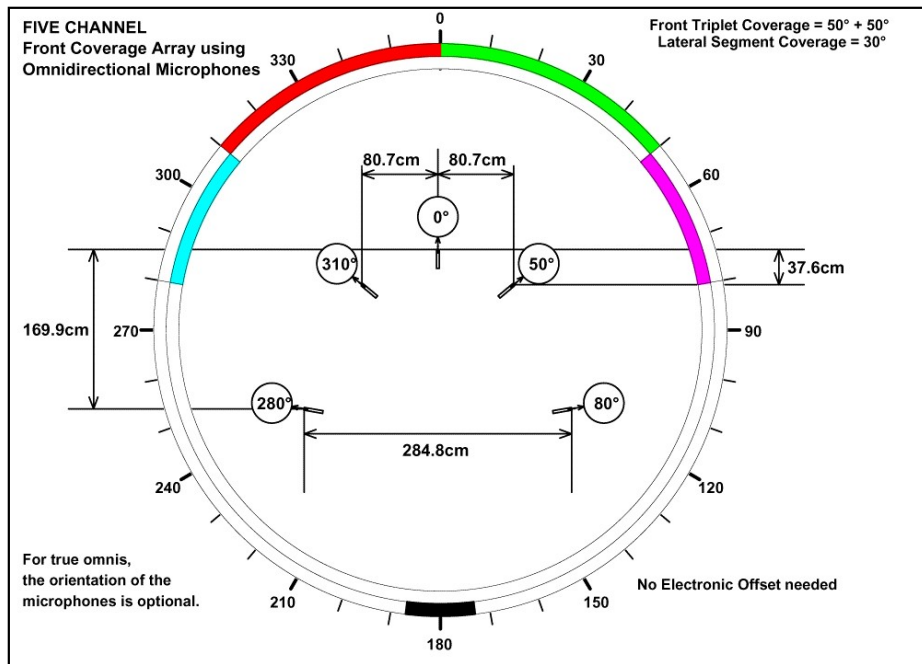


Figure 12

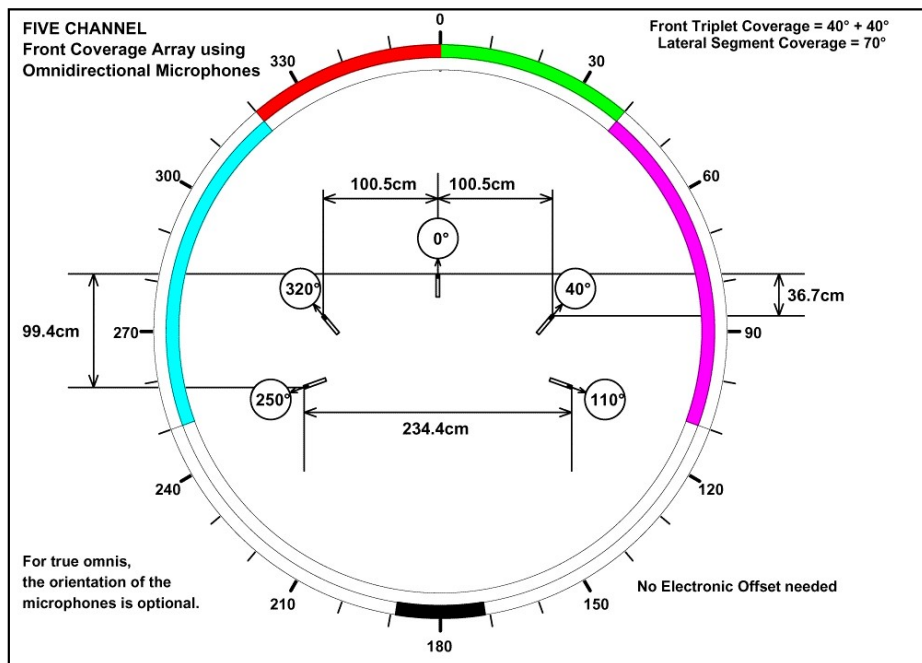


Figure 13

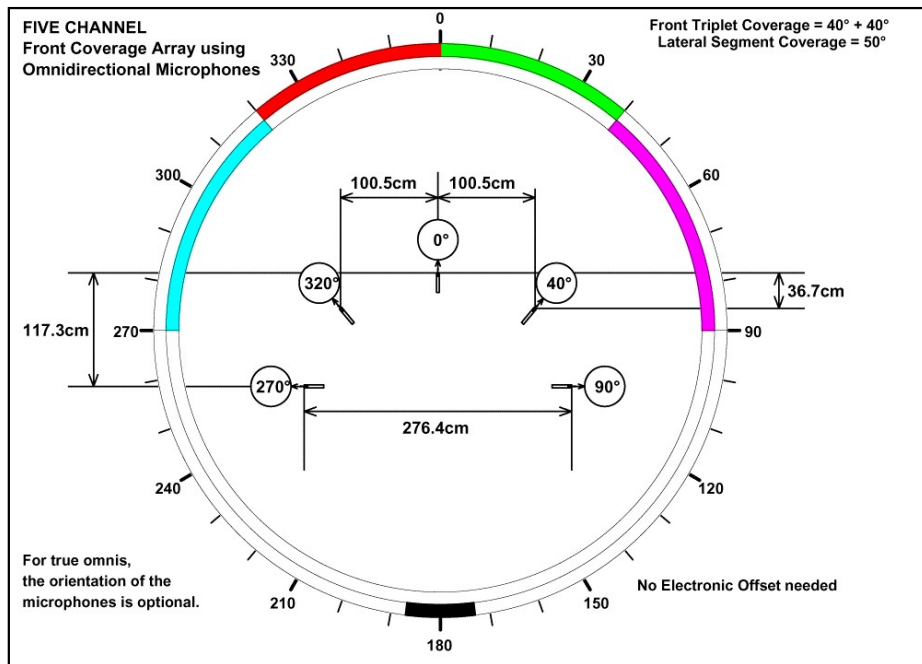


Figure 14

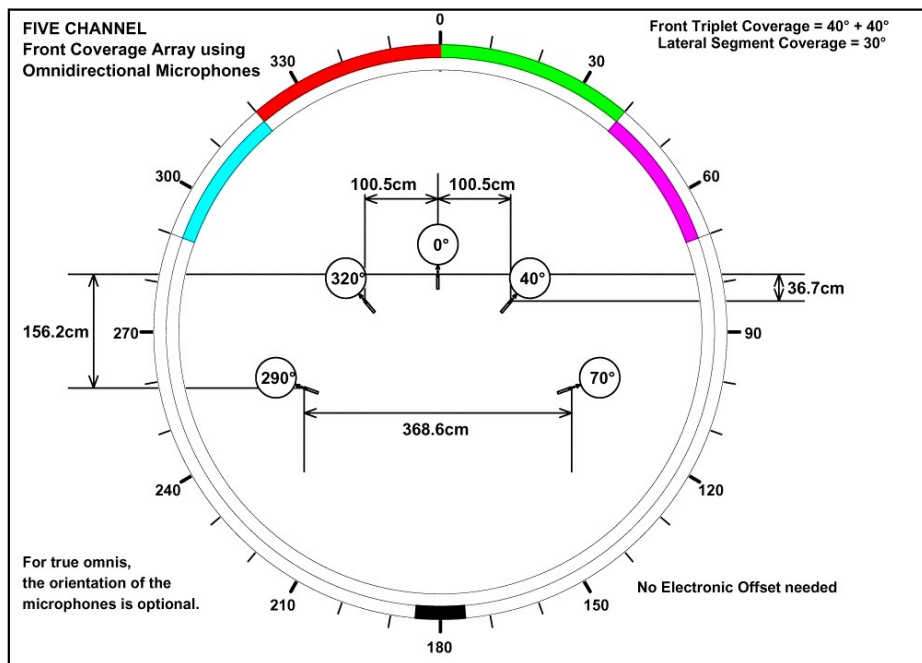


Figure 15

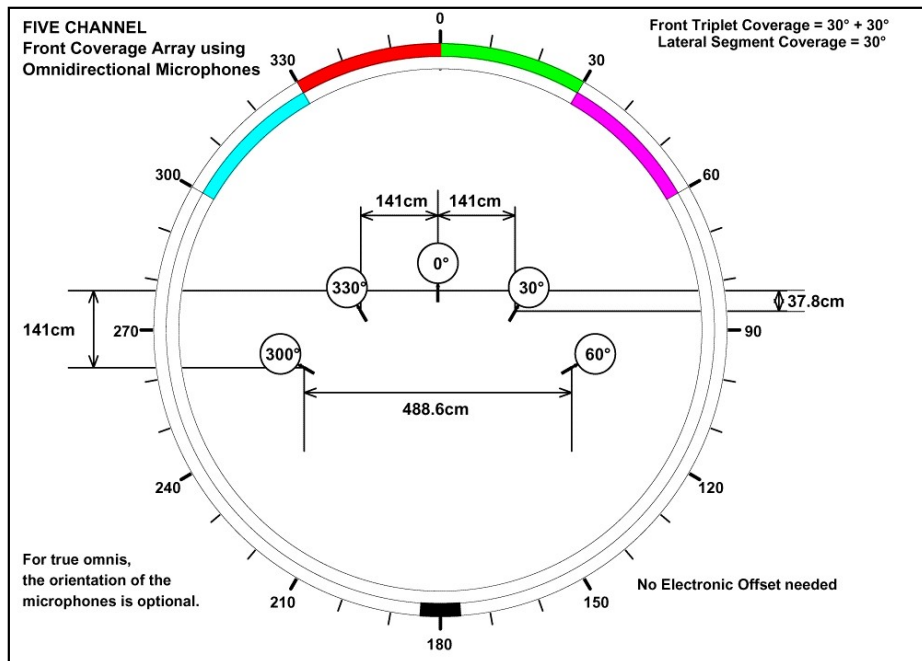


Figure 18

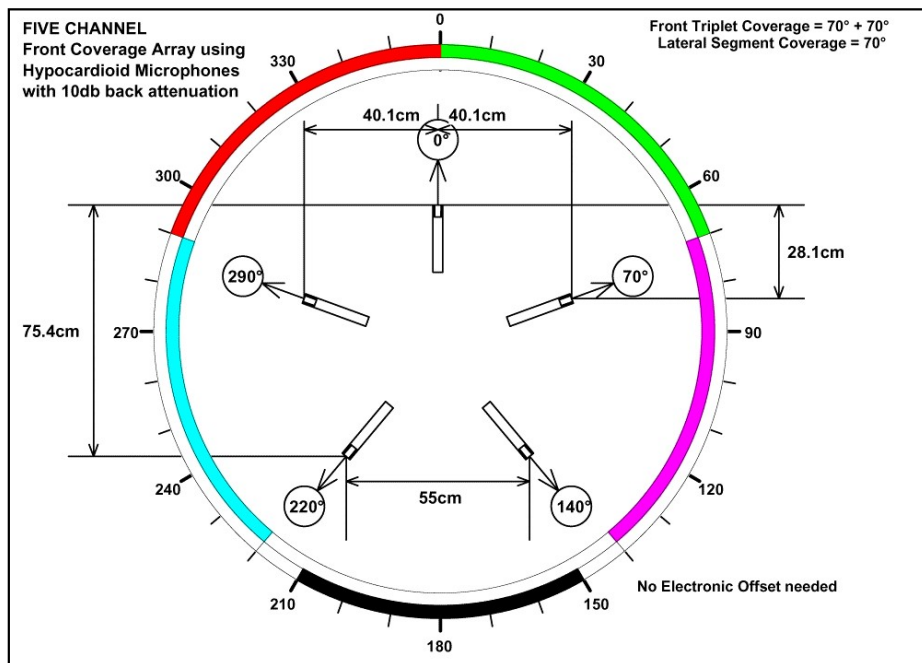


Figure 19

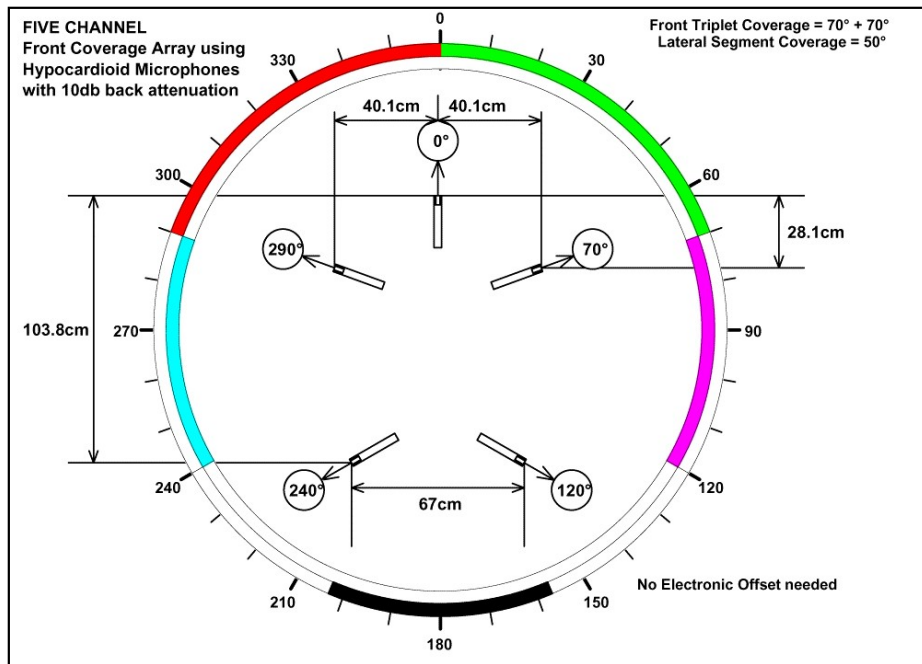


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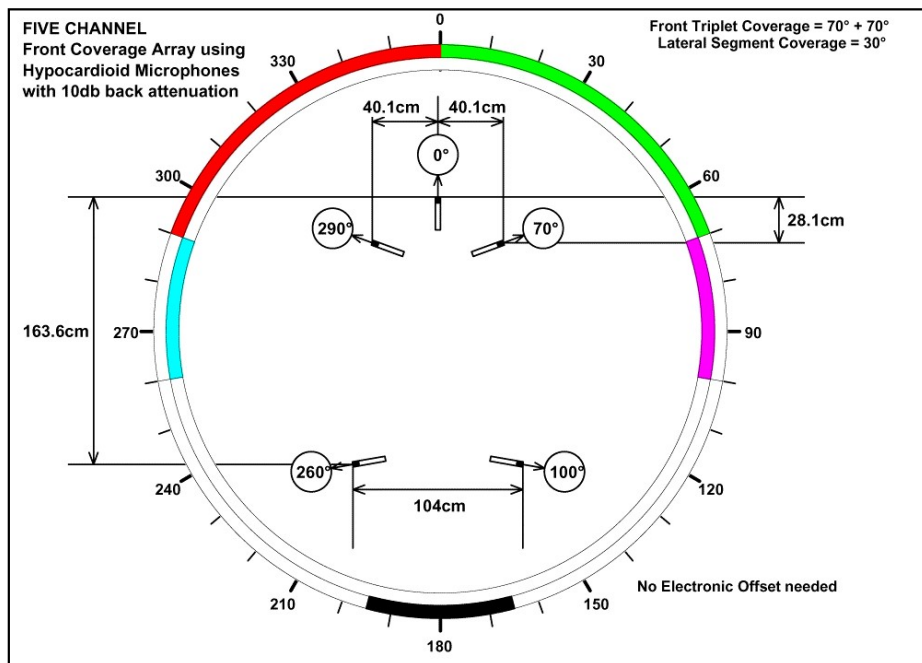


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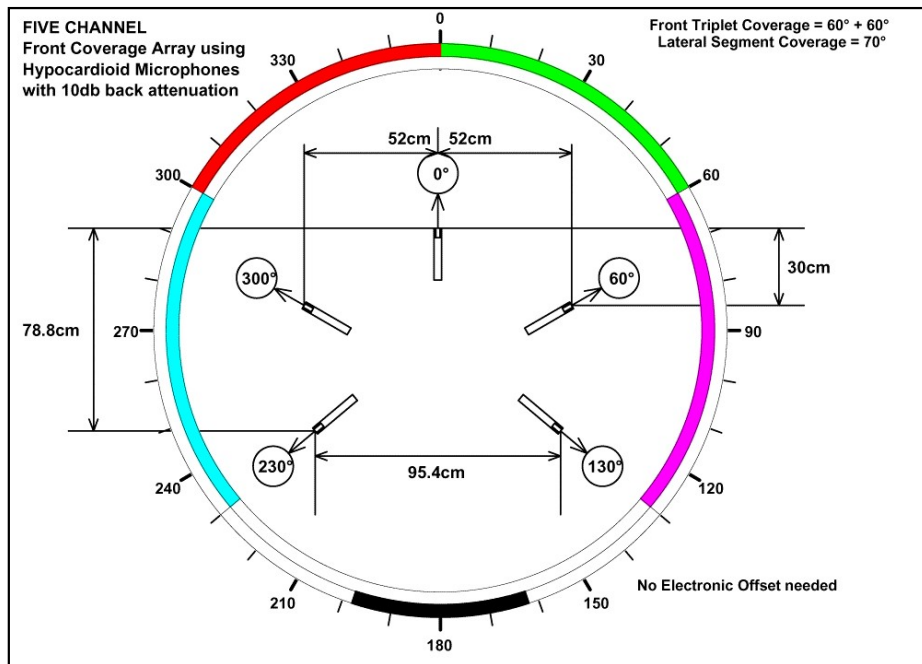


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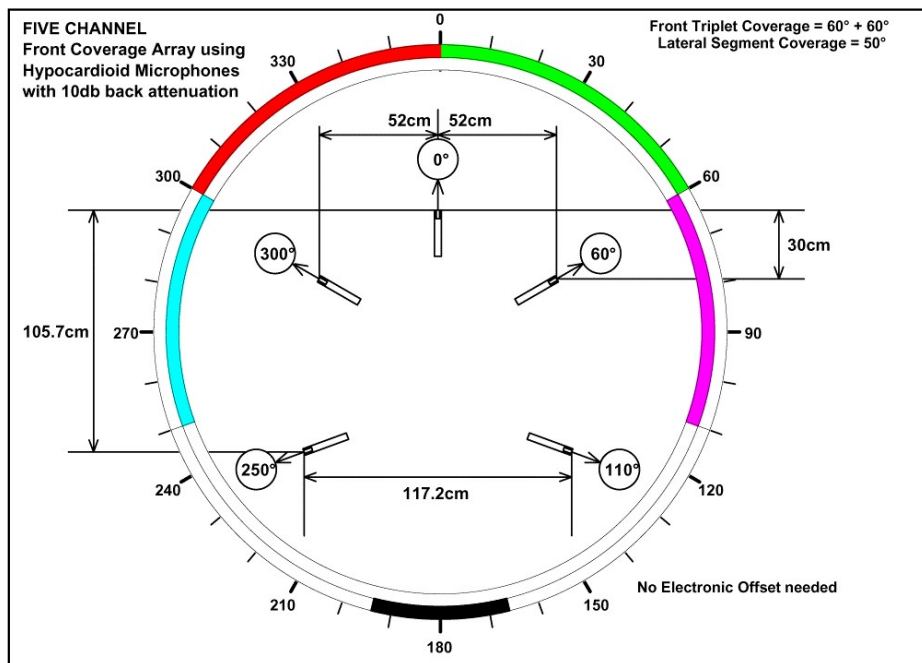


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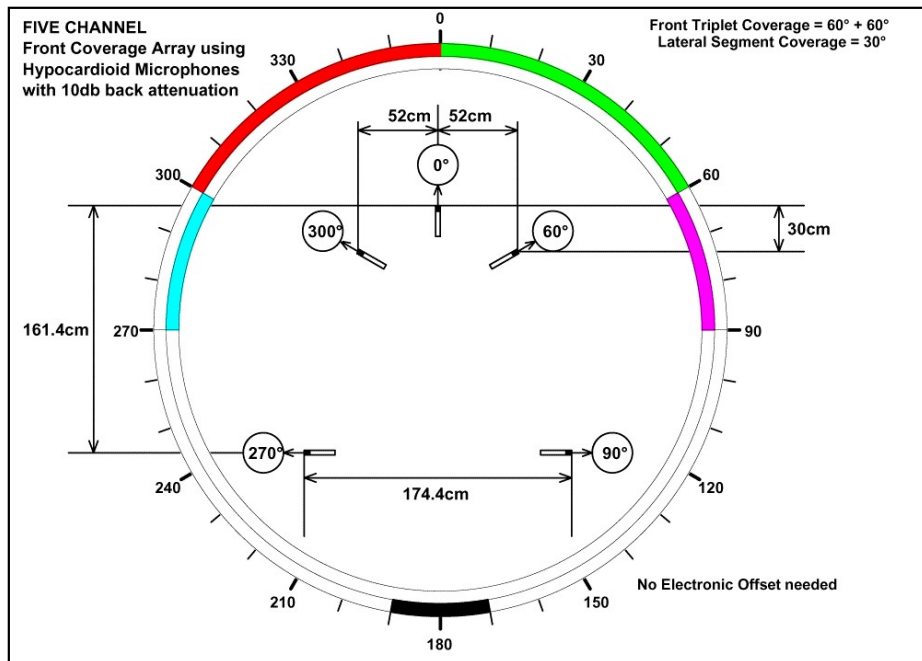


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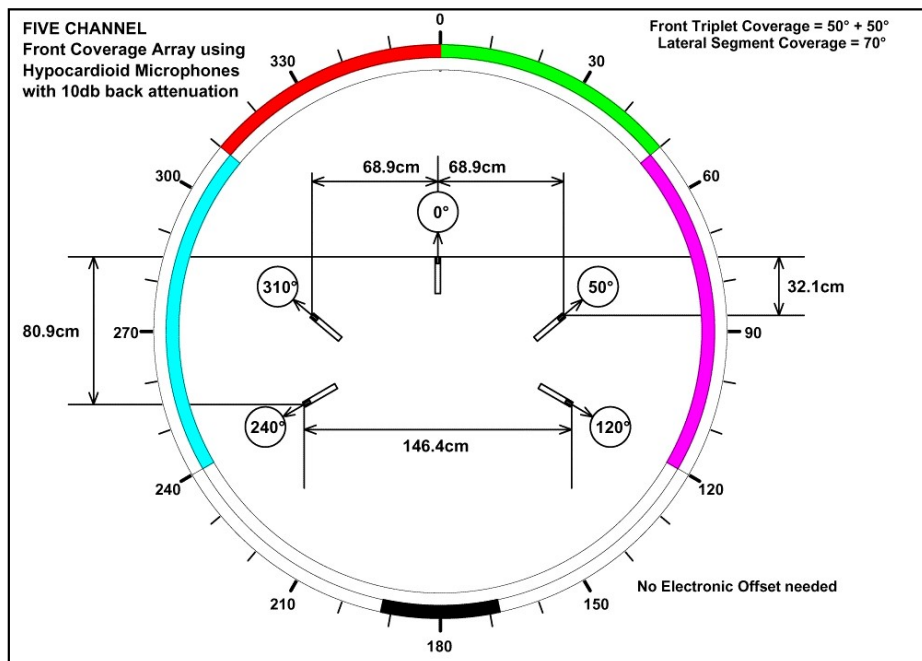


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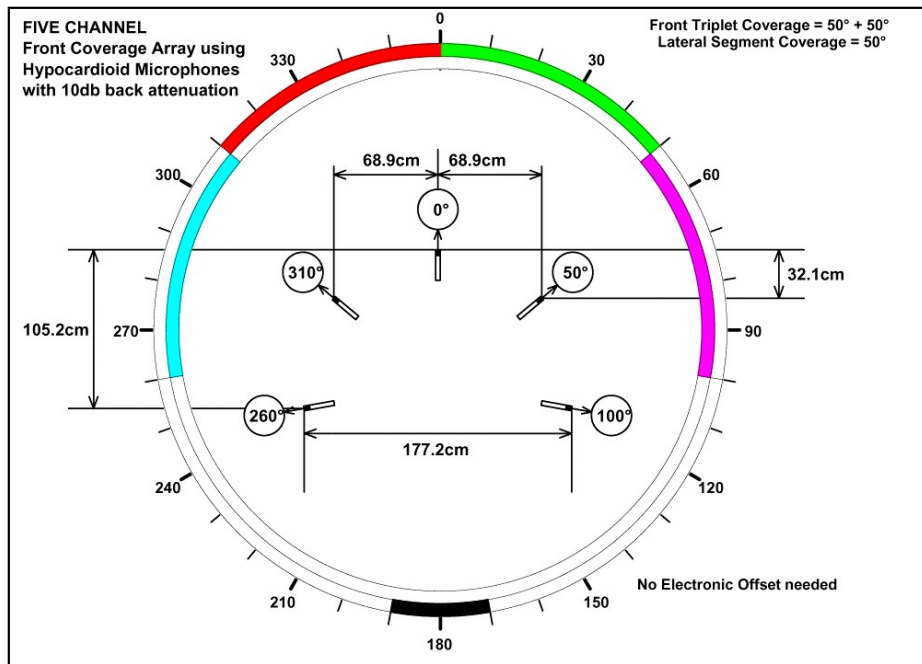


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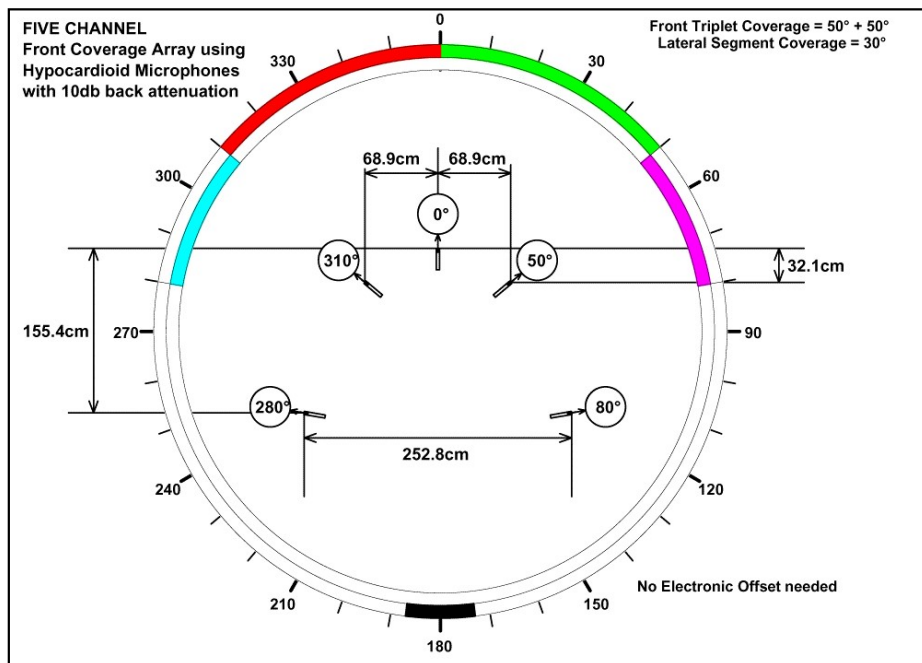


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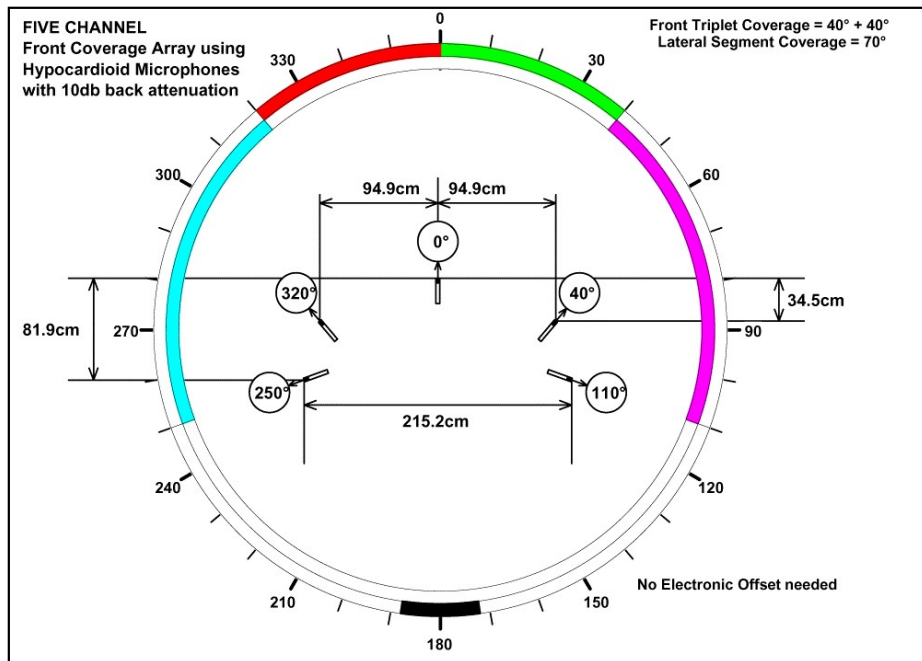


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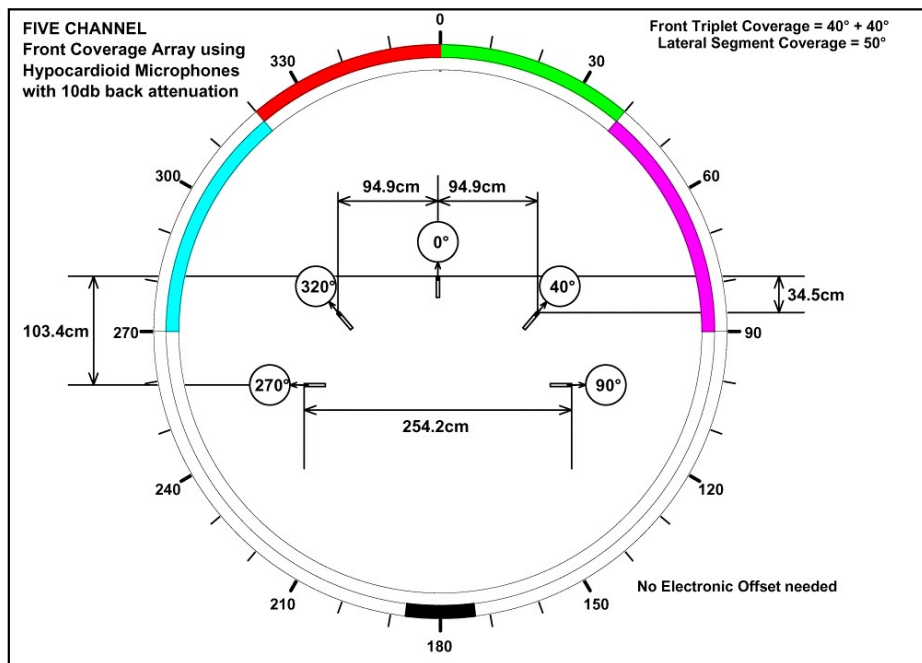


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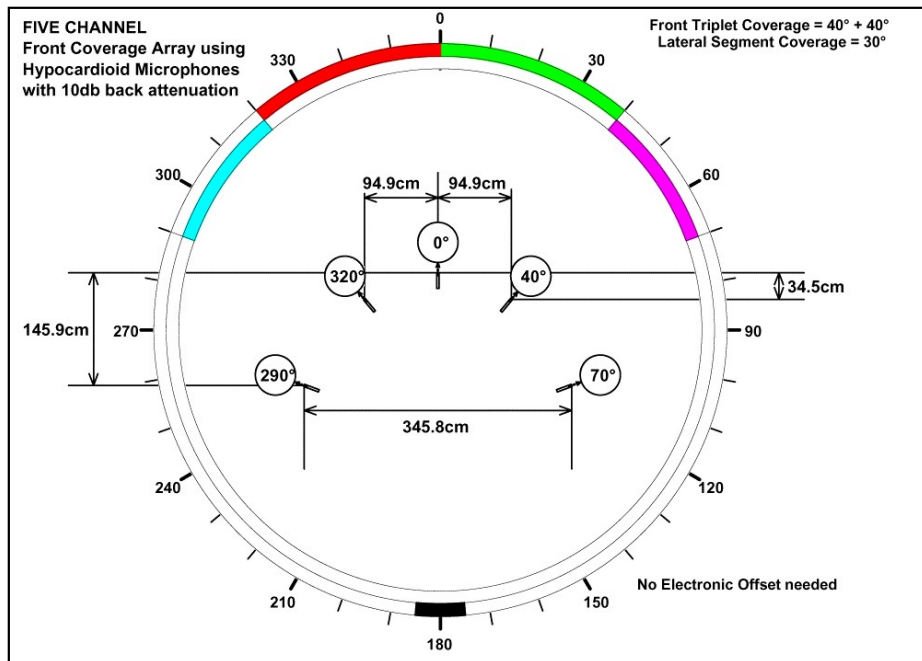


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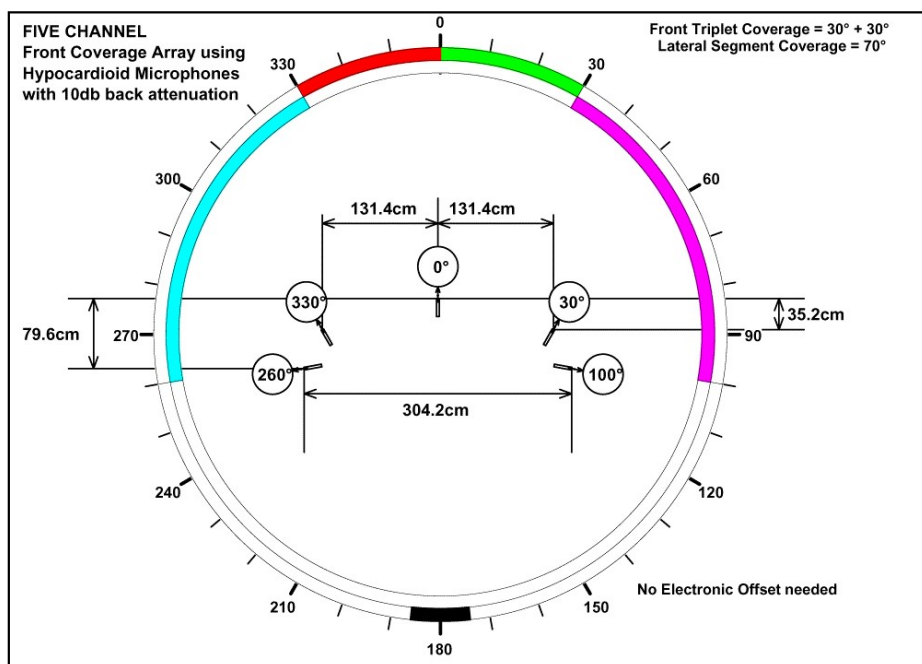


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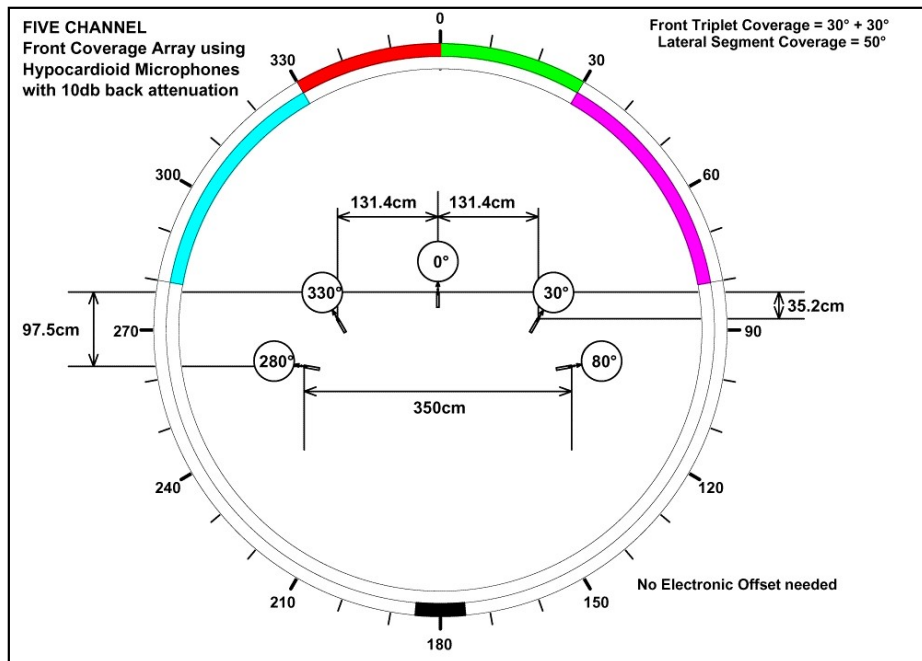


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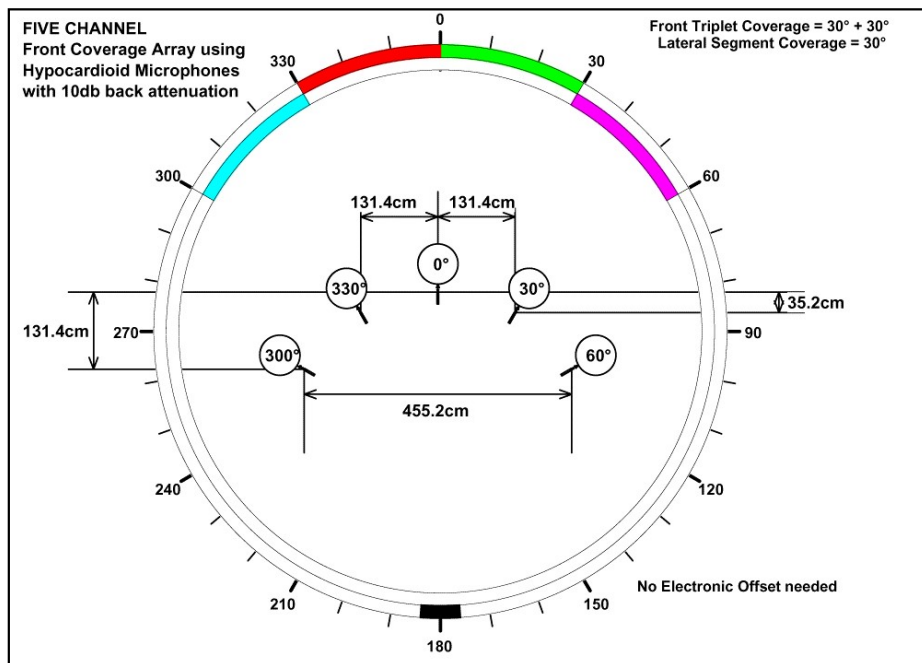


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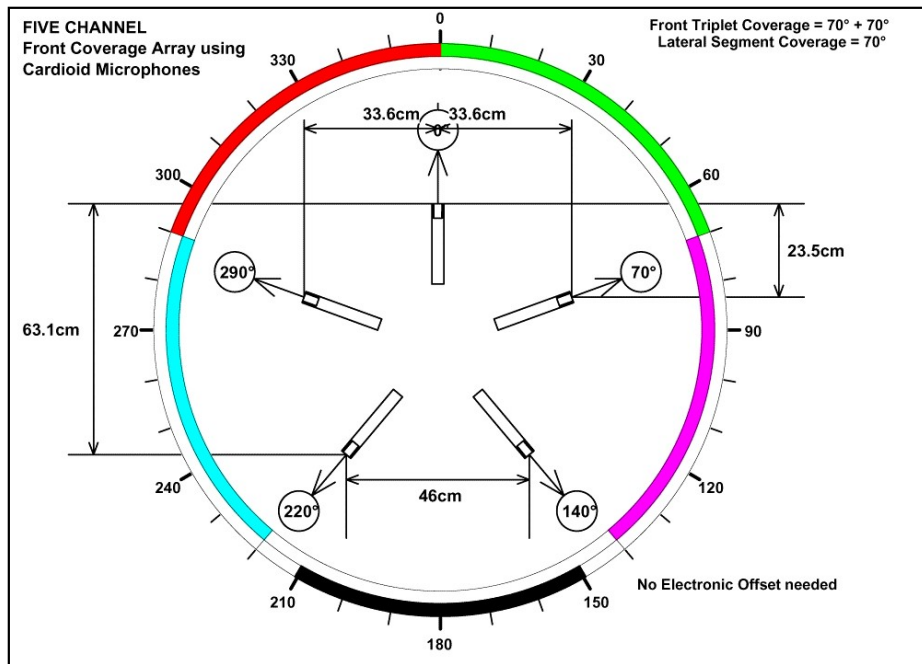


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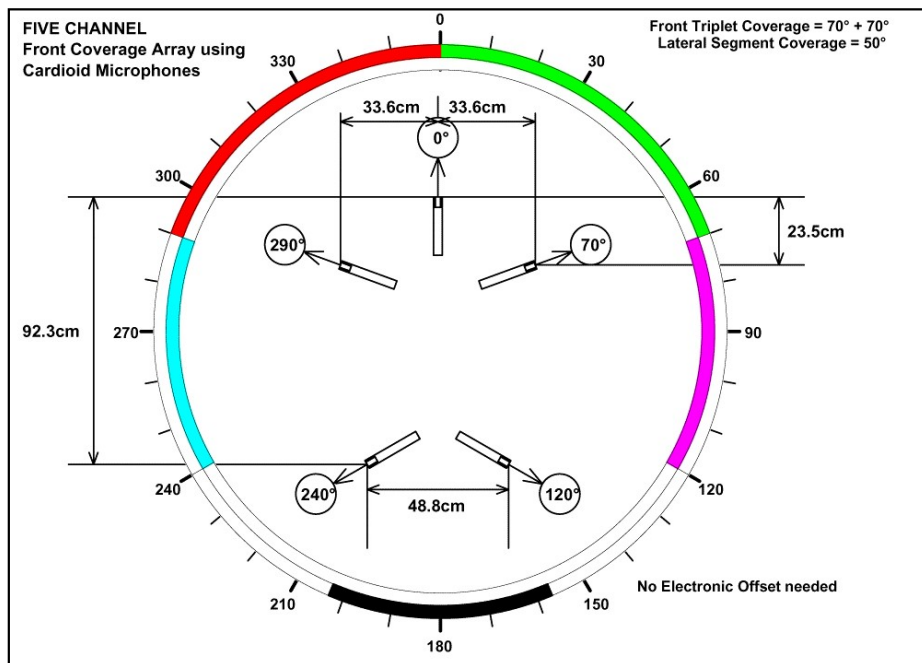


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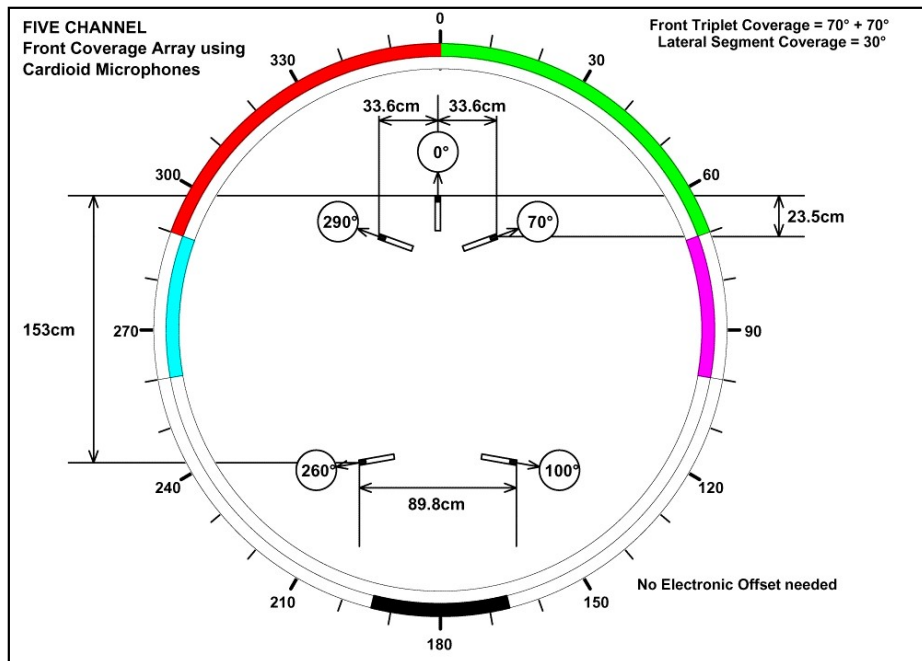


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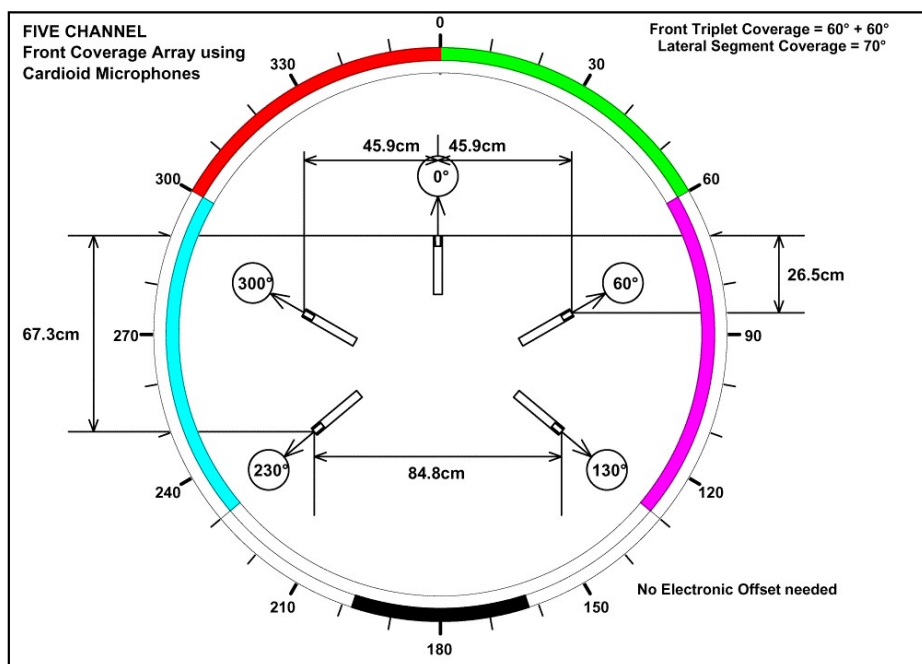


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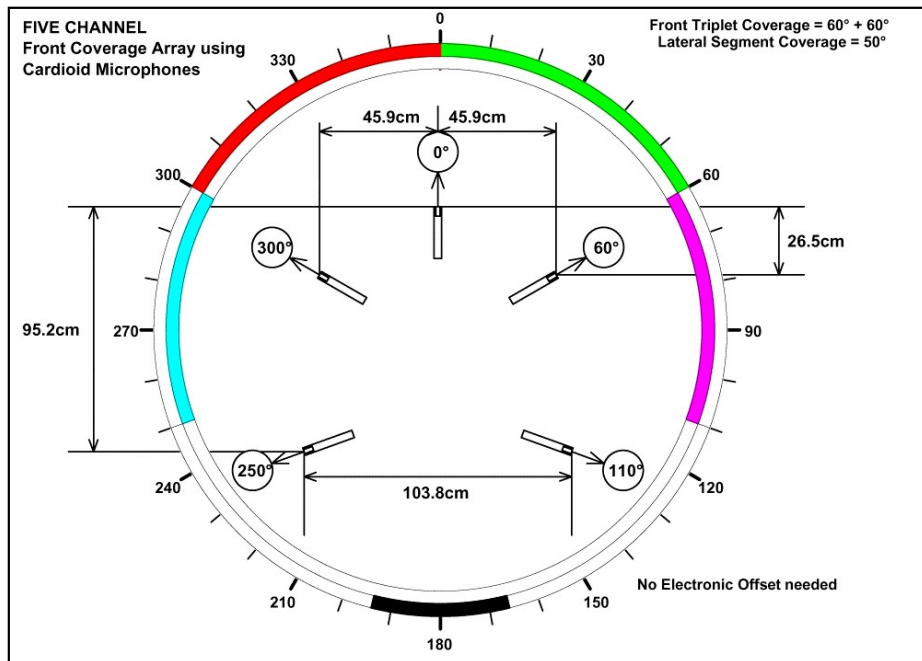


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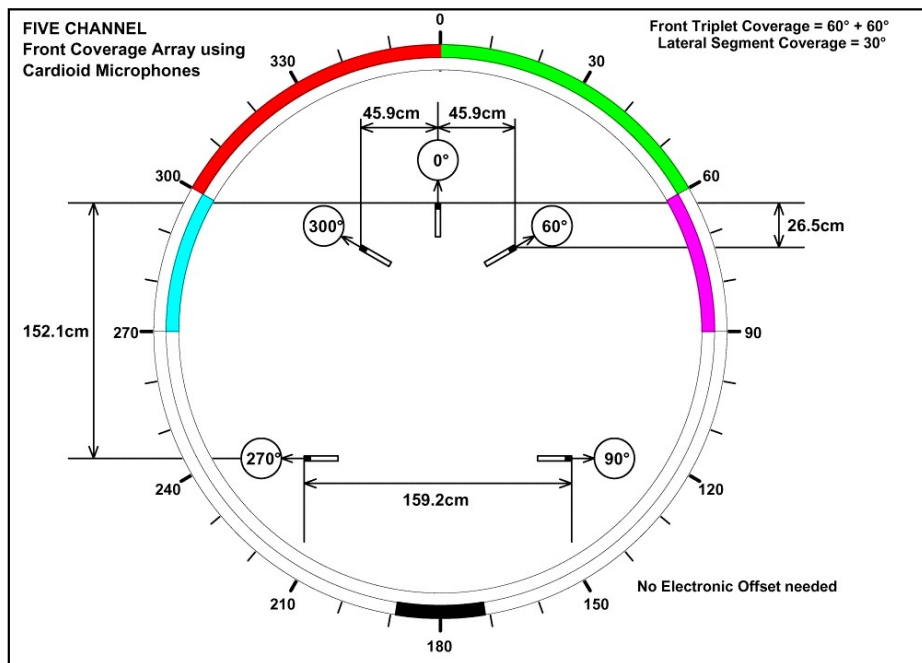


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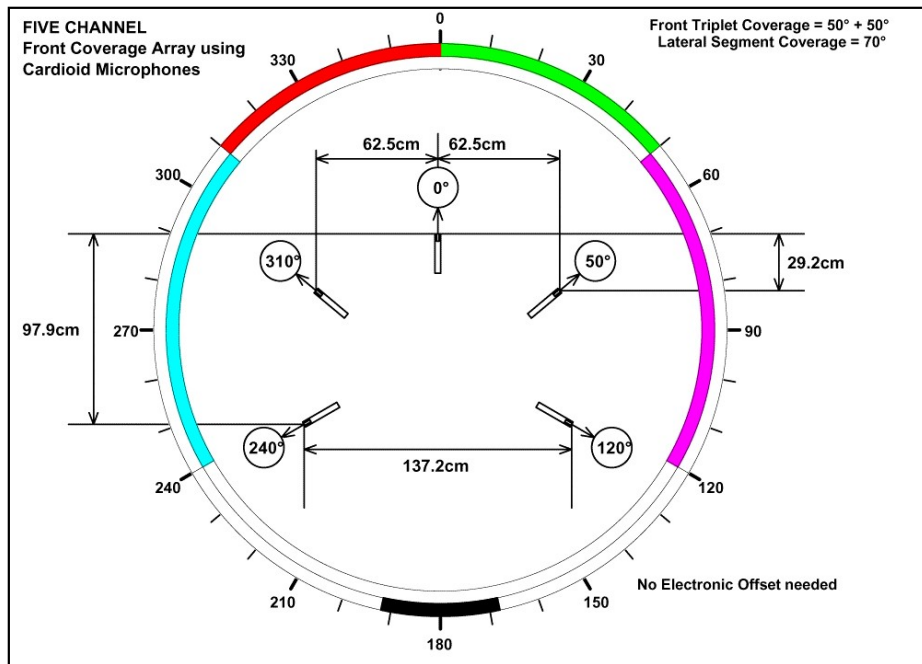


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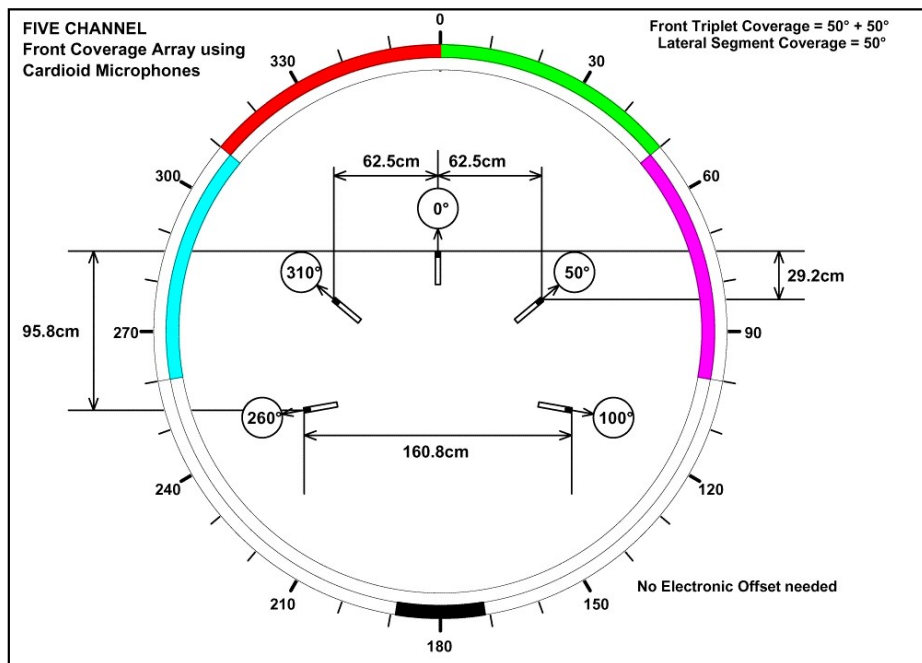


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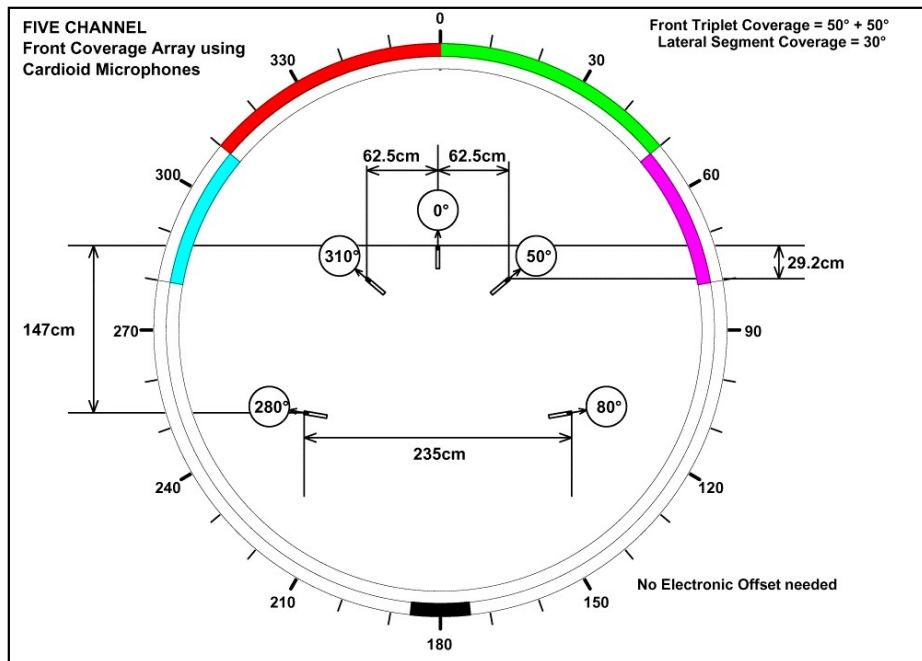


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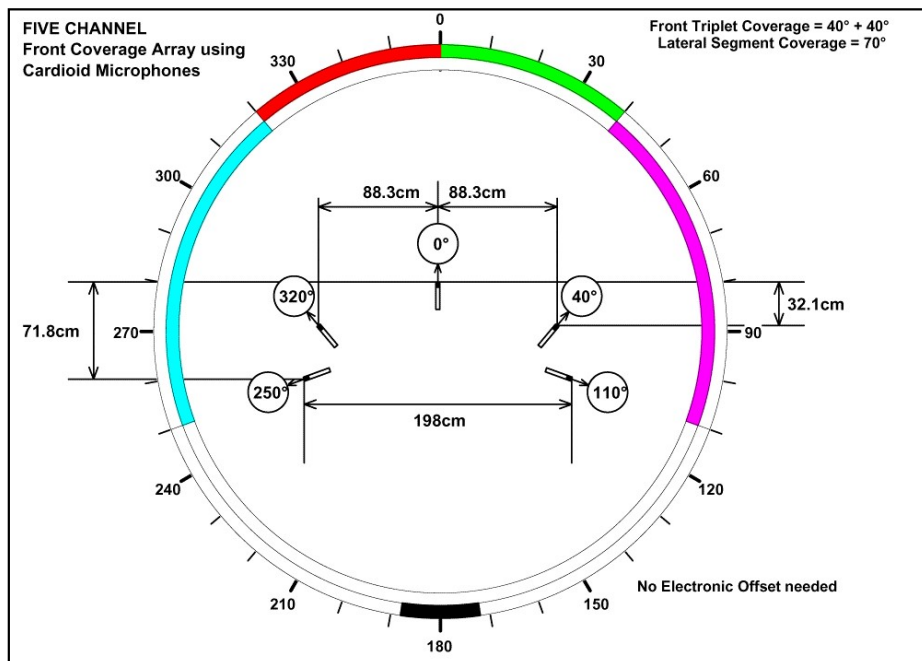


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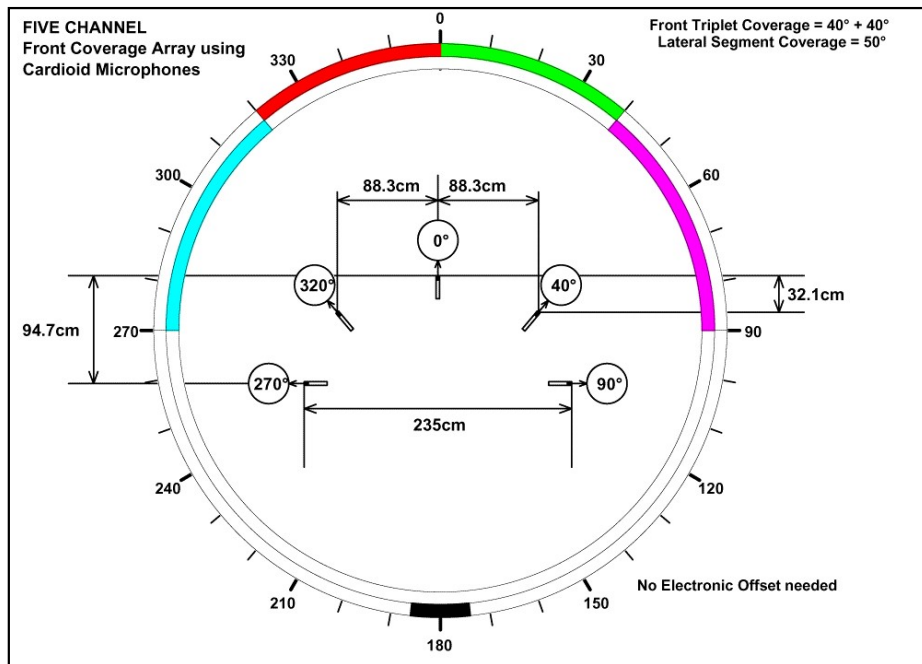


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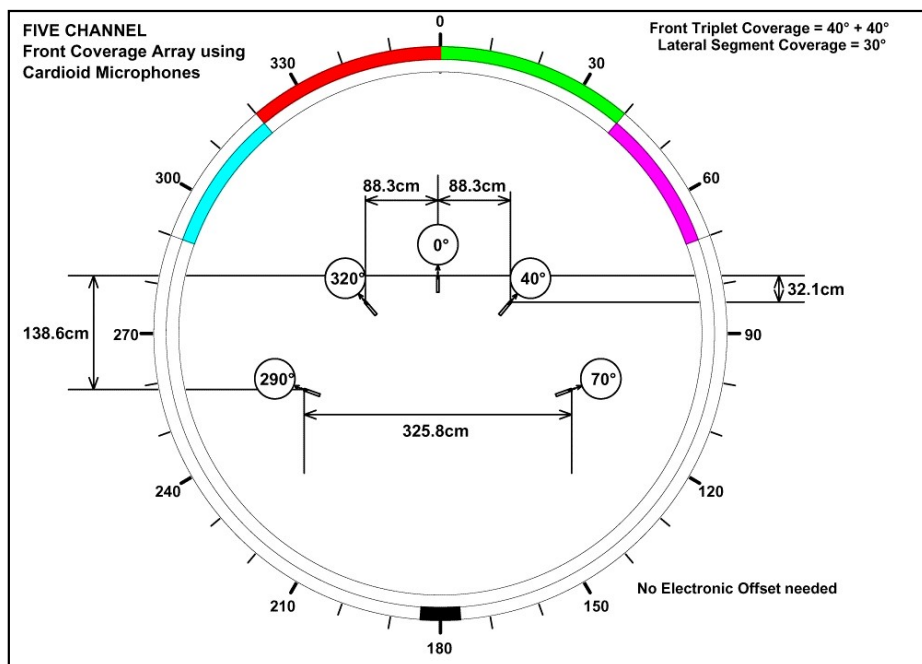


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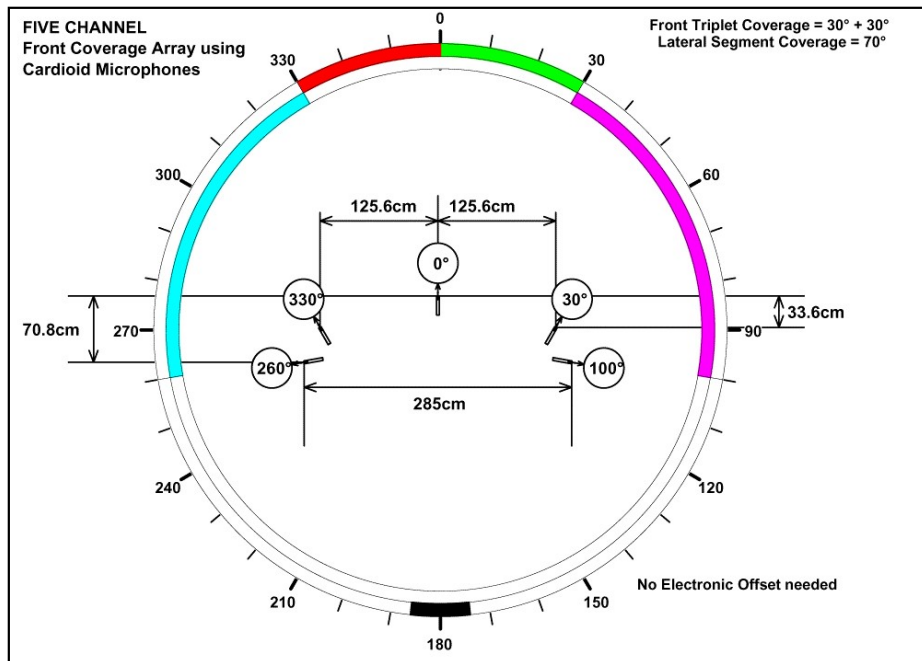


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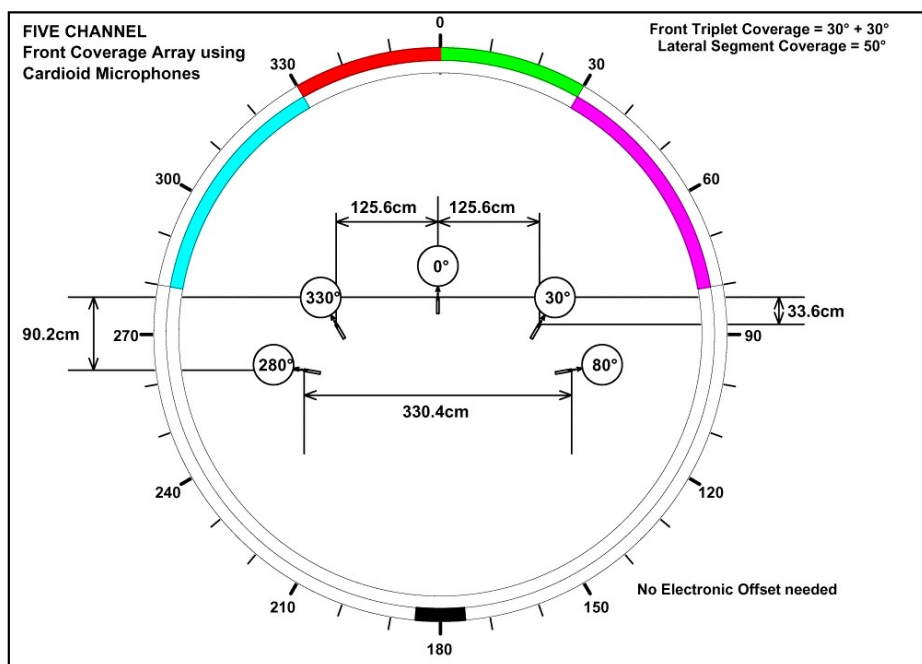


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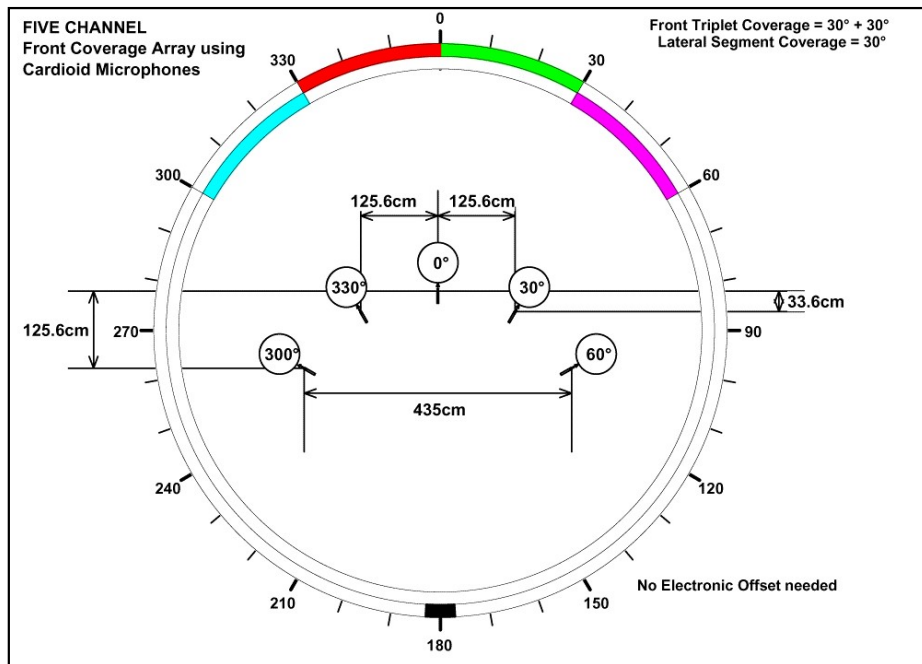


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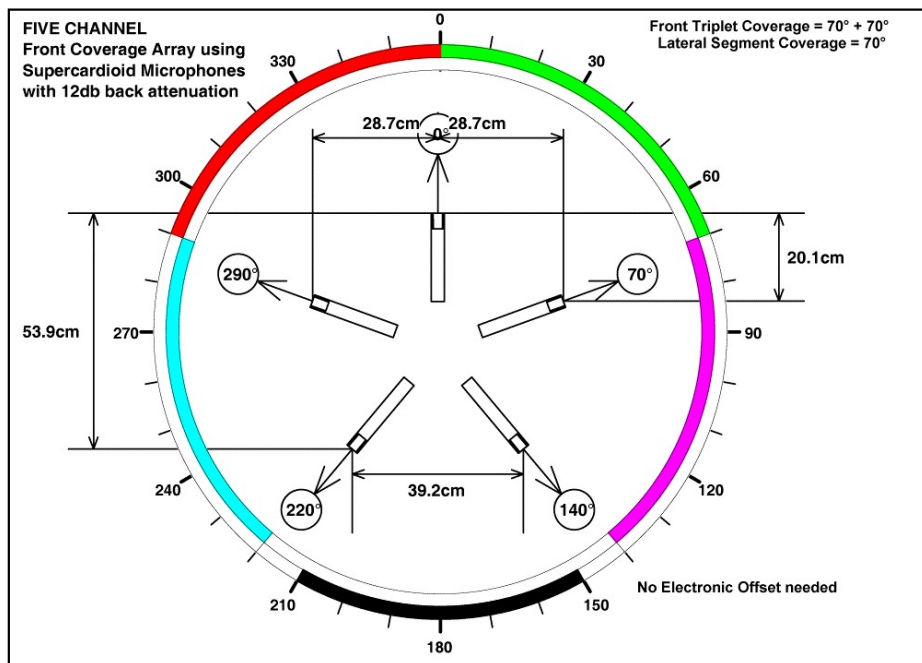


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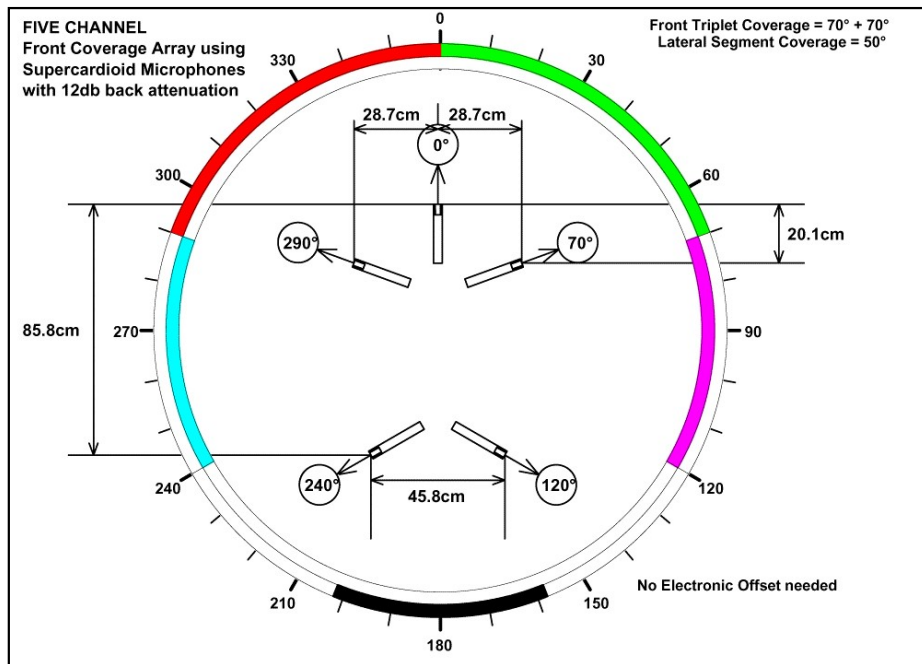


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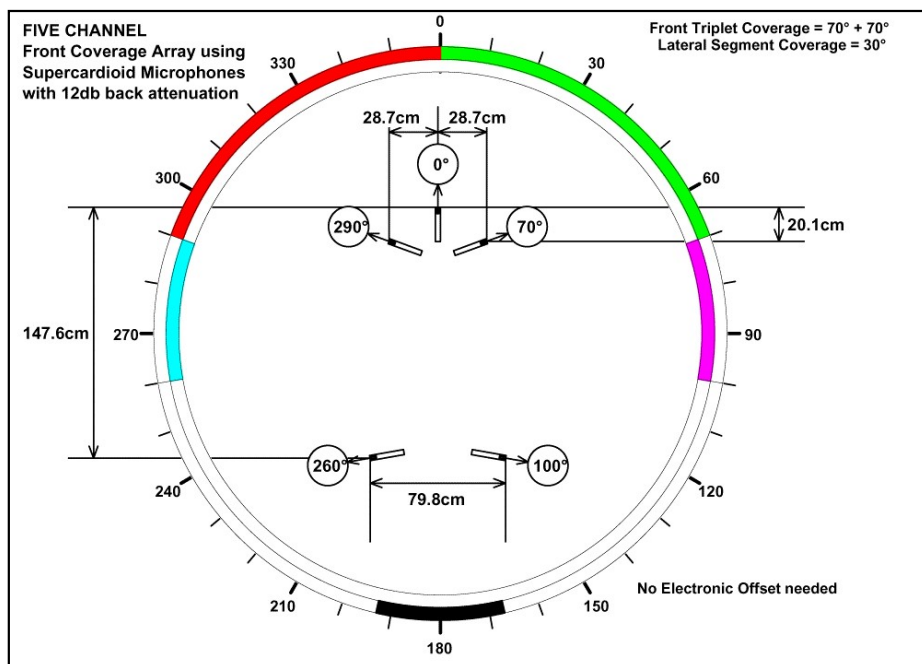


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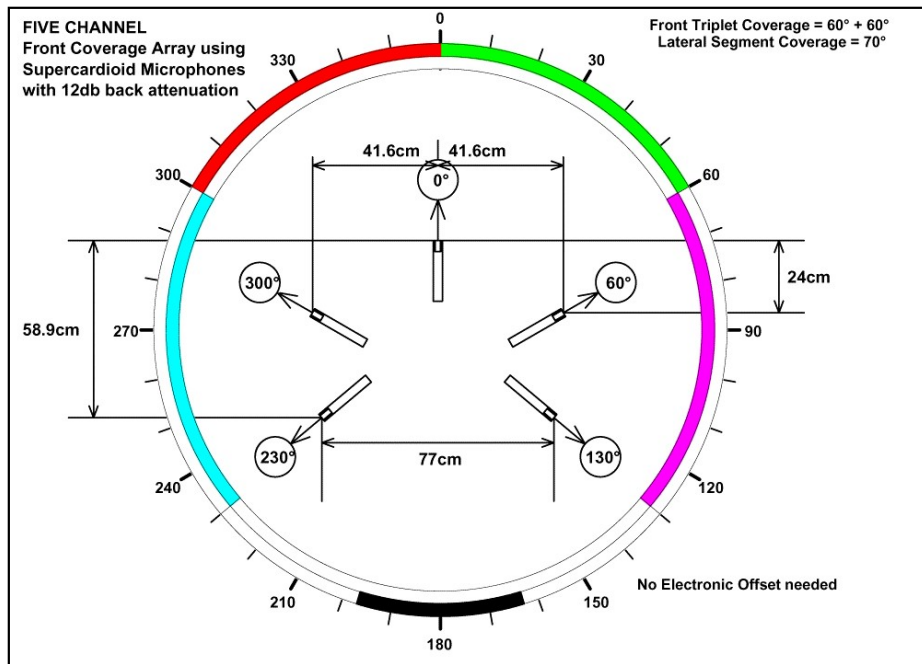


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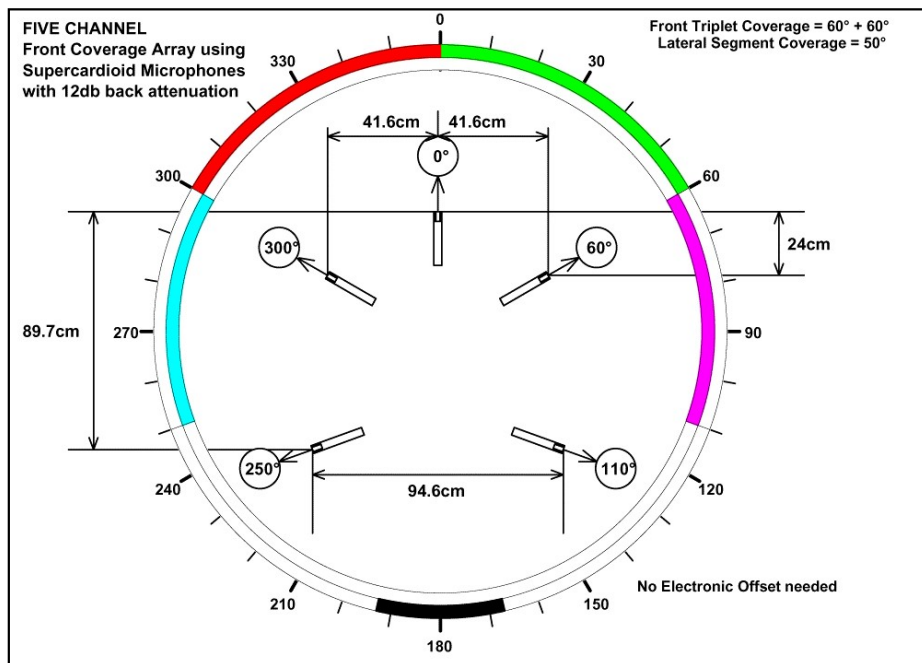


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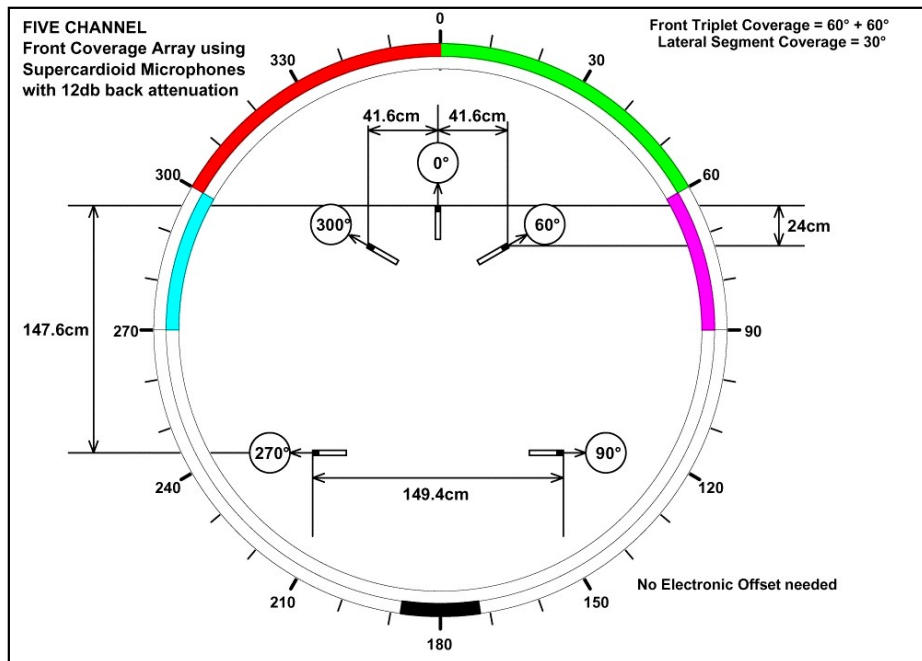


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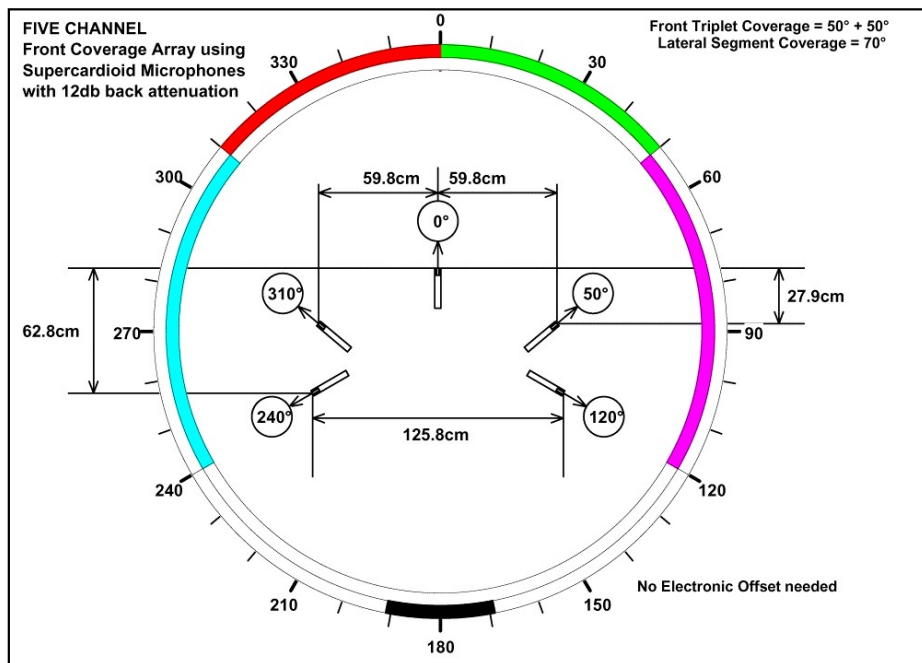


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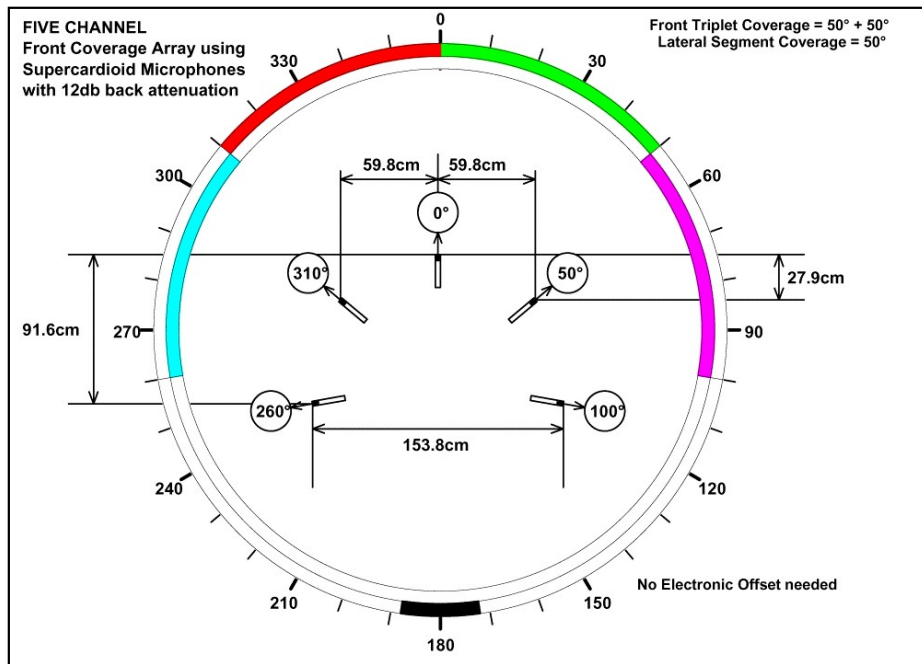


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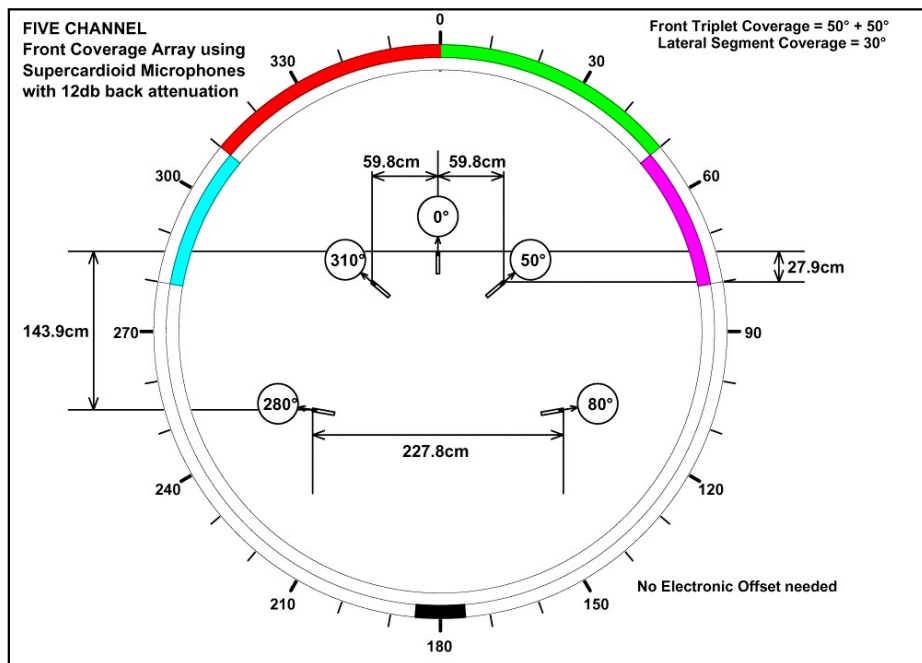


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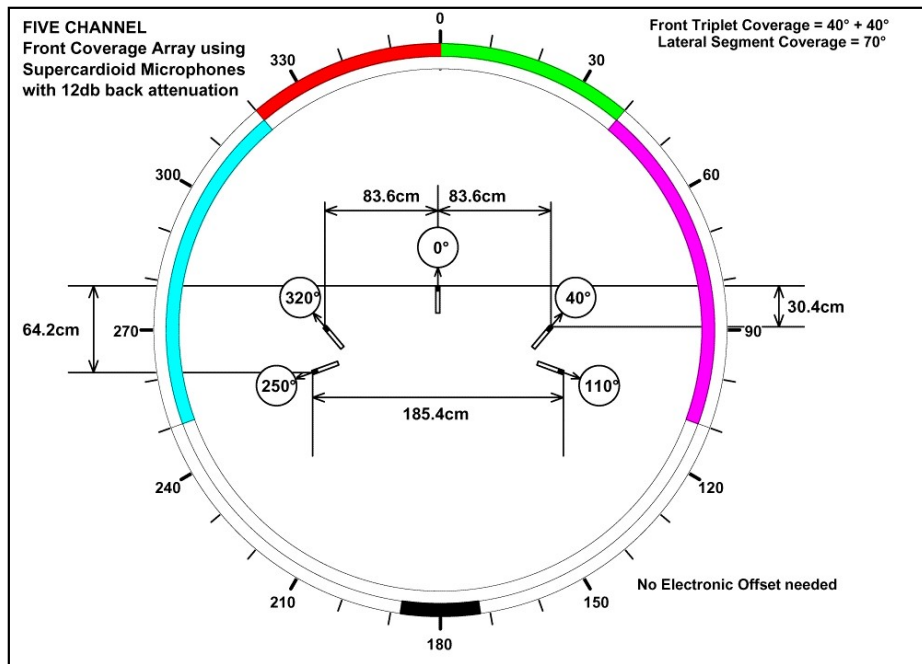


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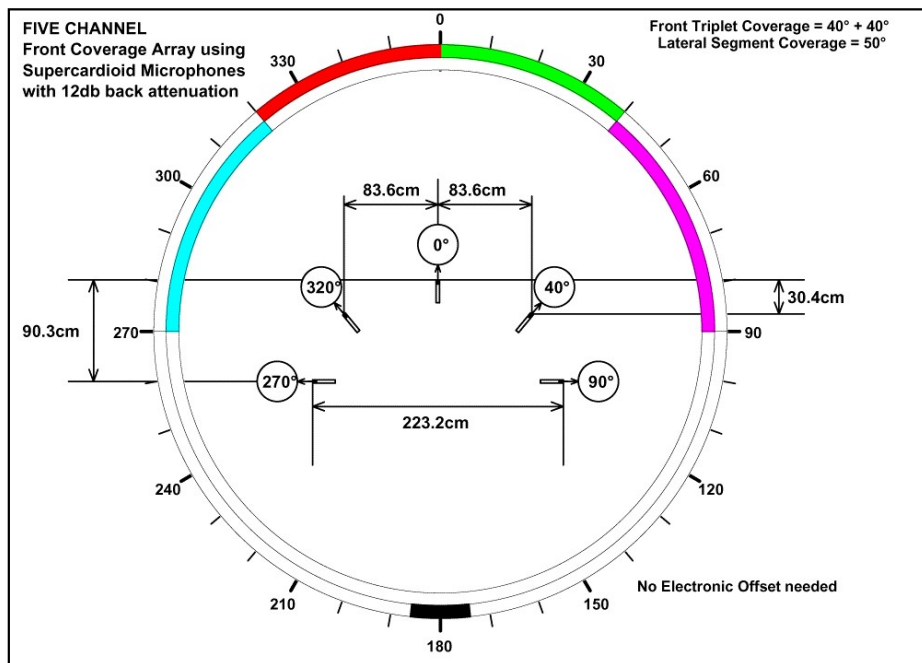


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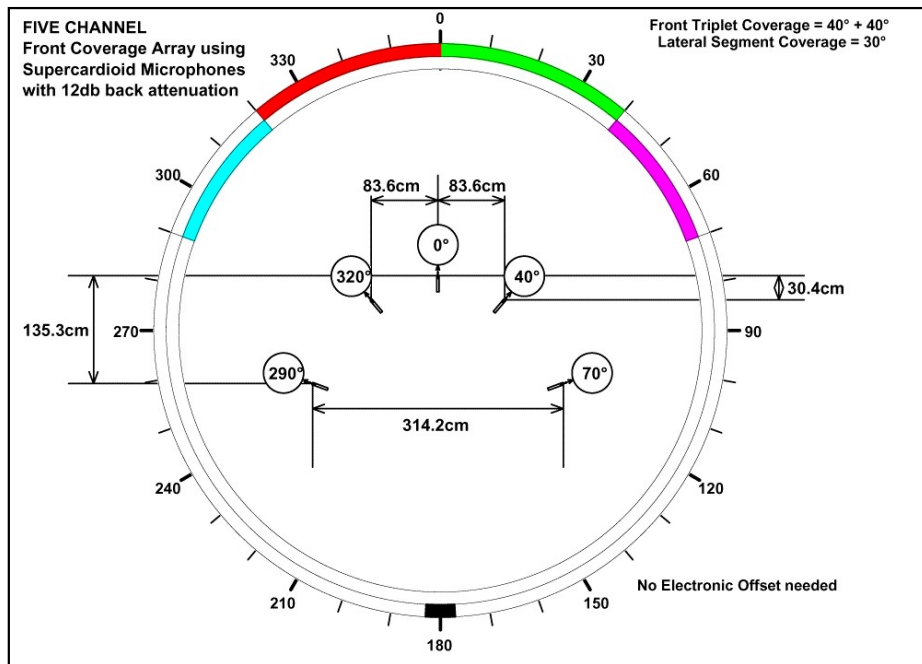


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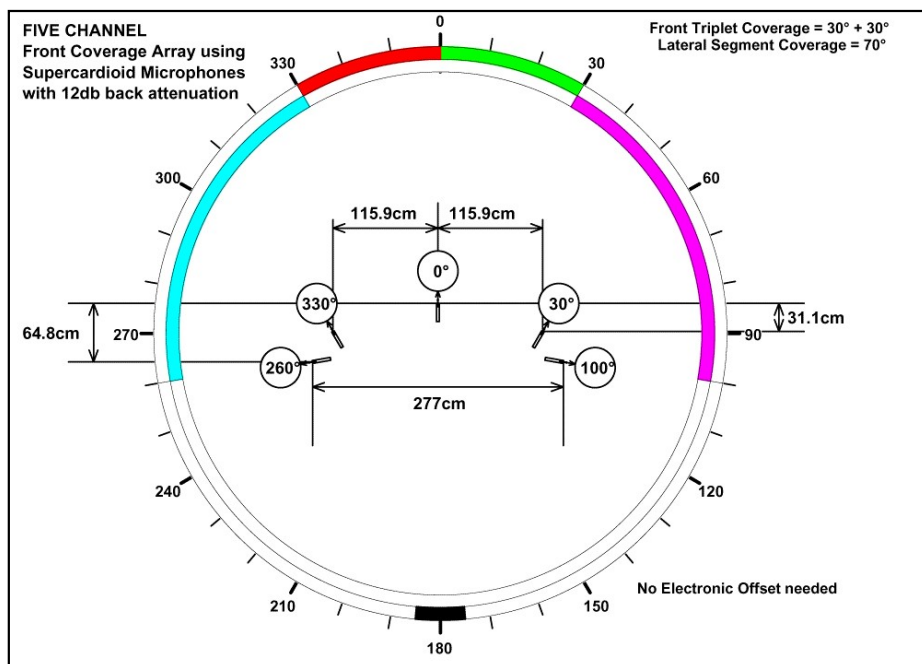


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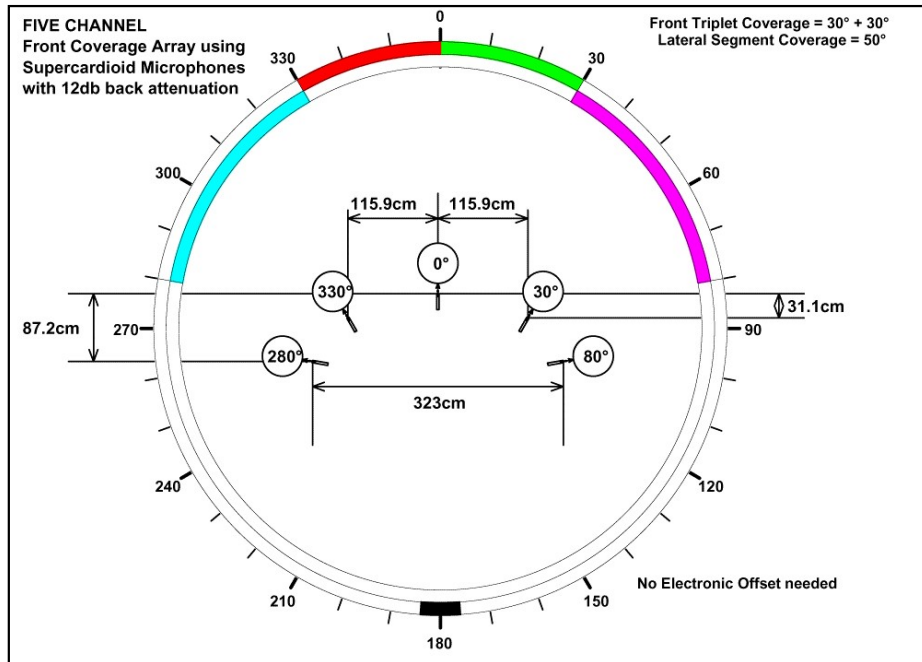


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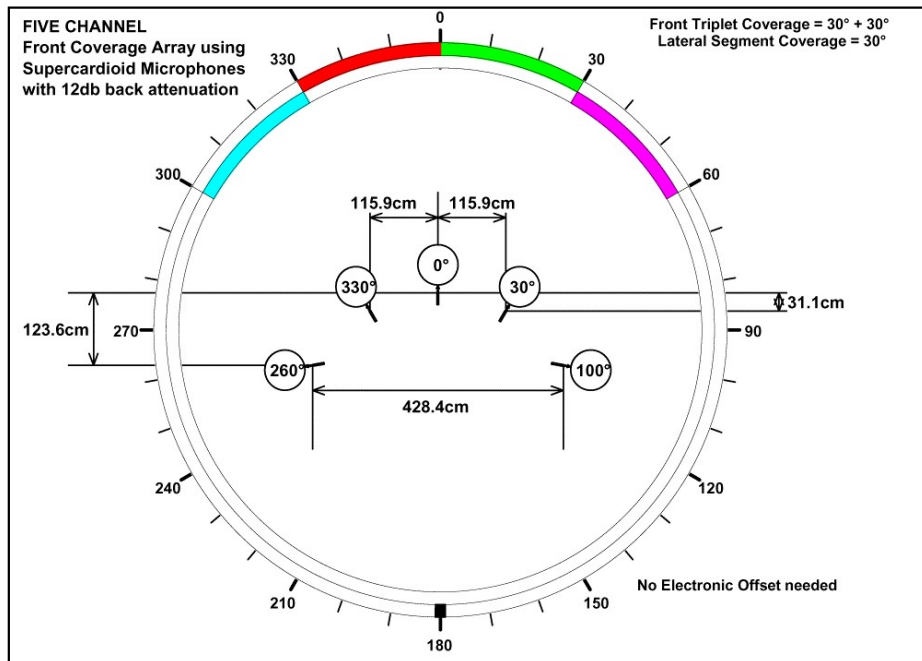


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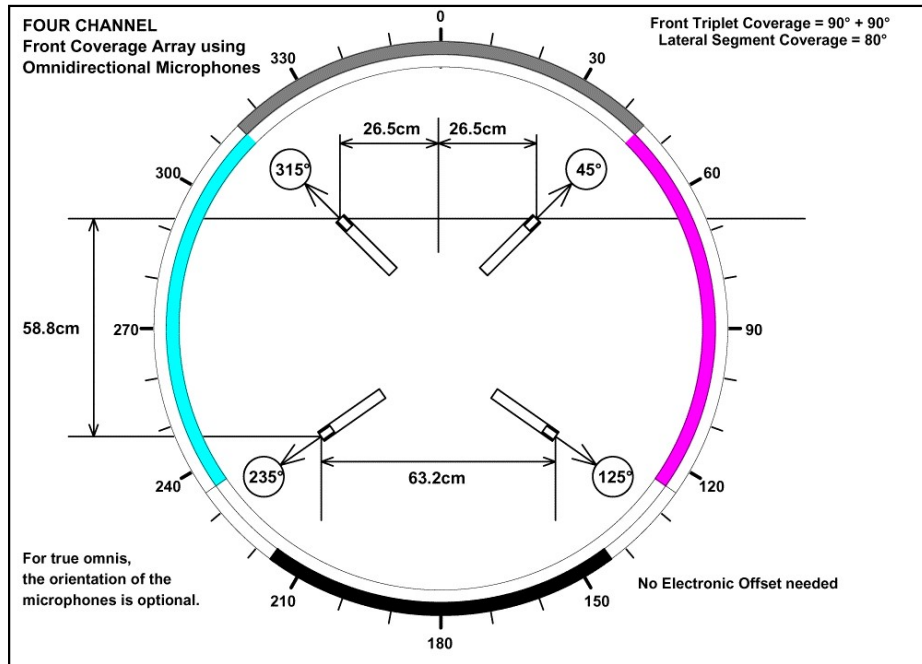


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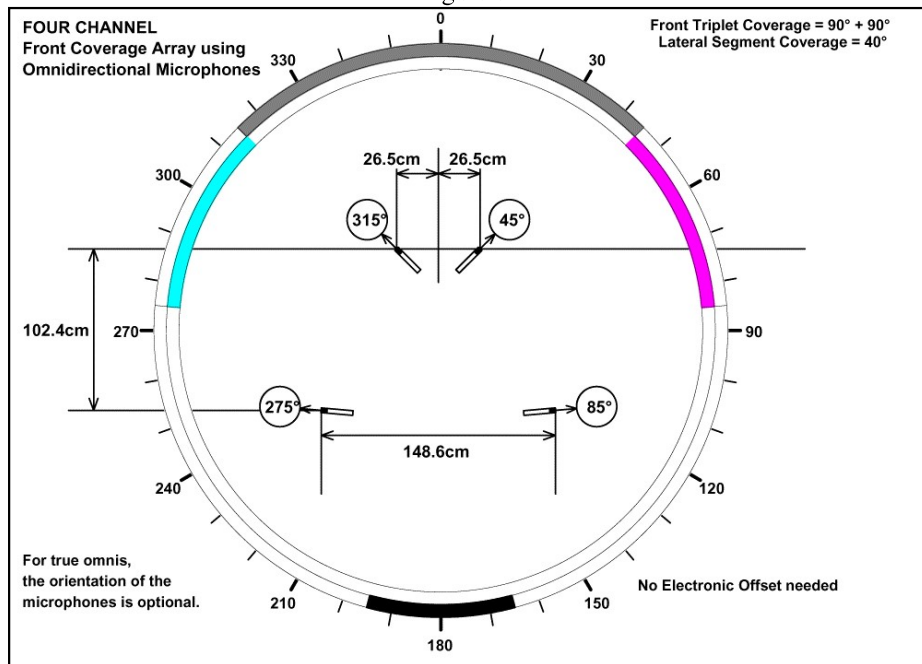


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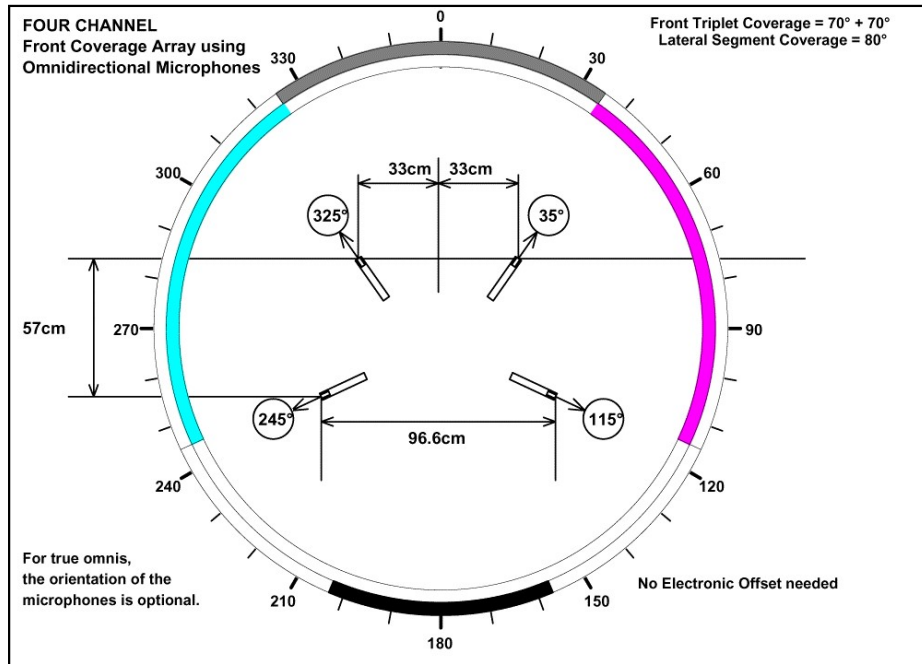


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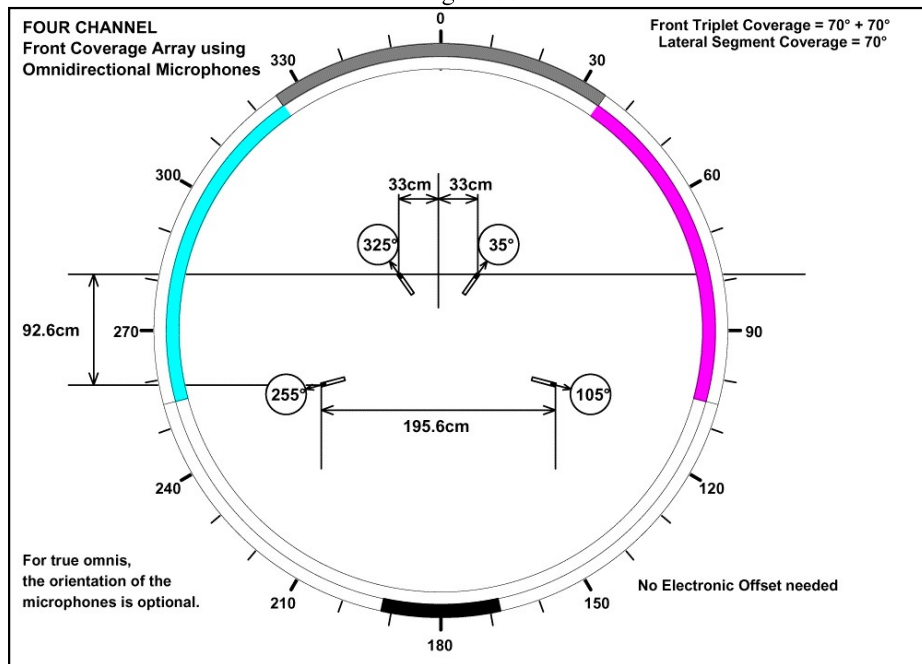


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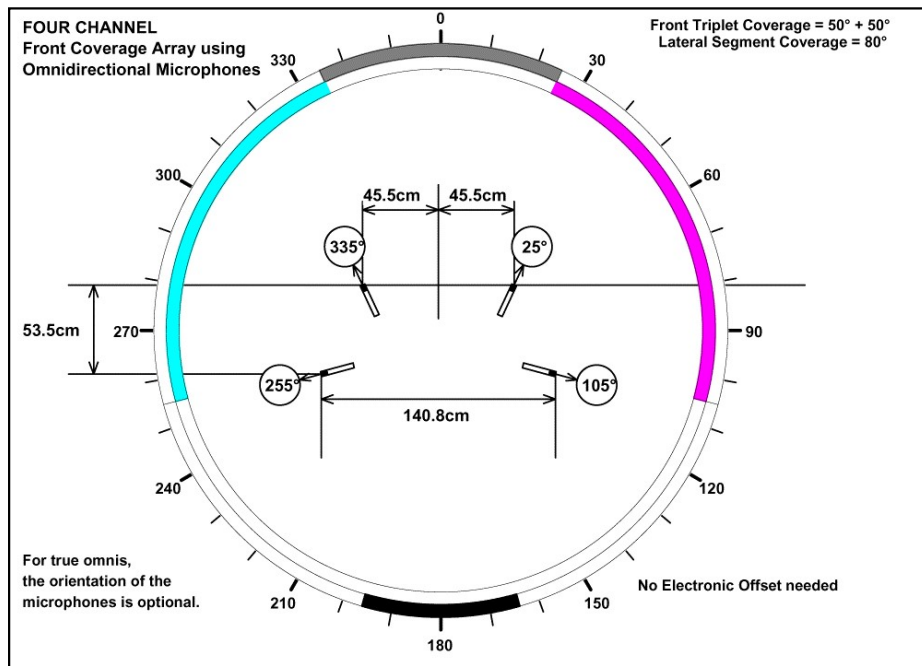


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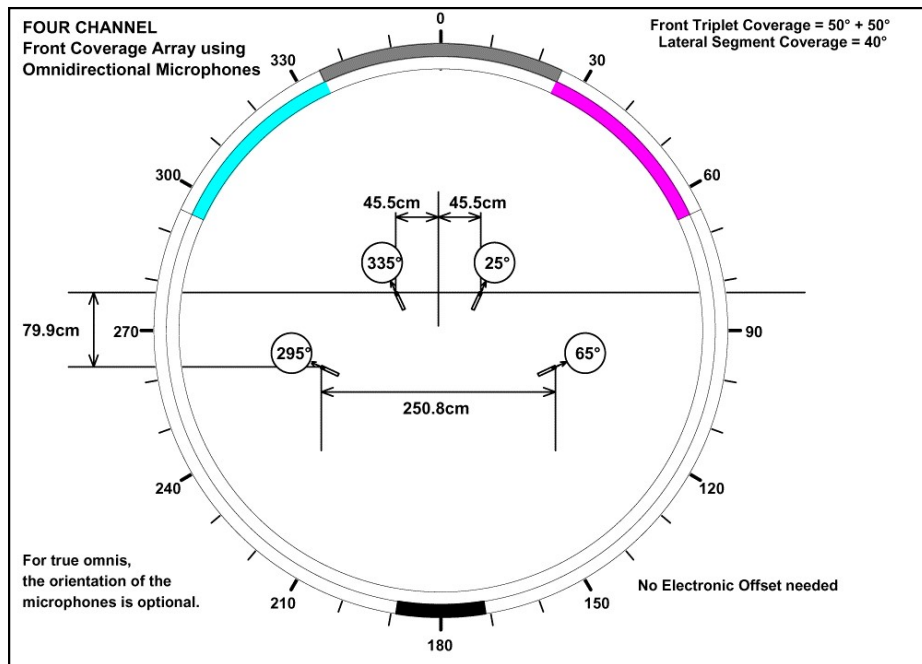


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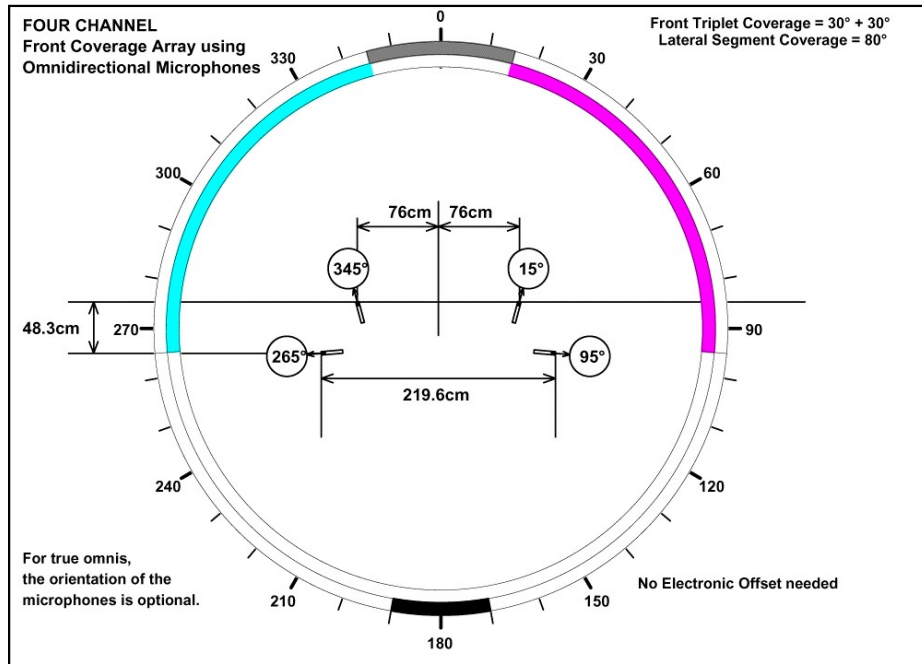


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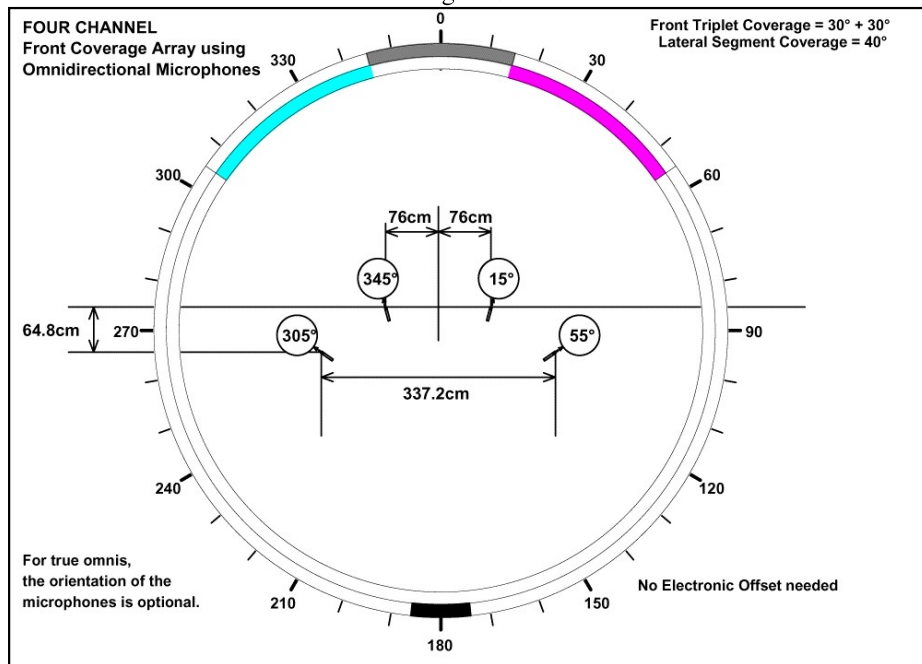


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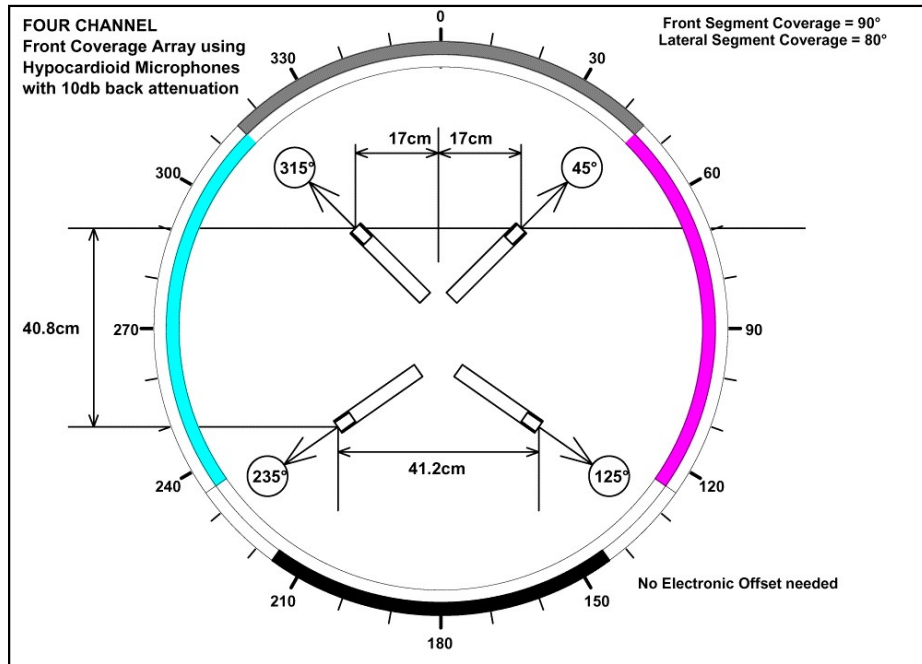


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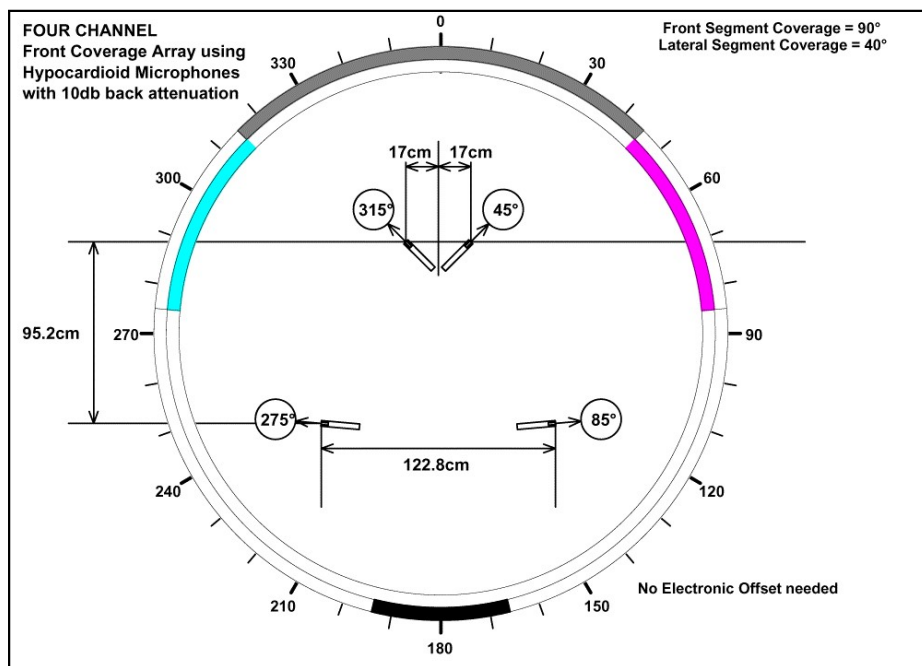


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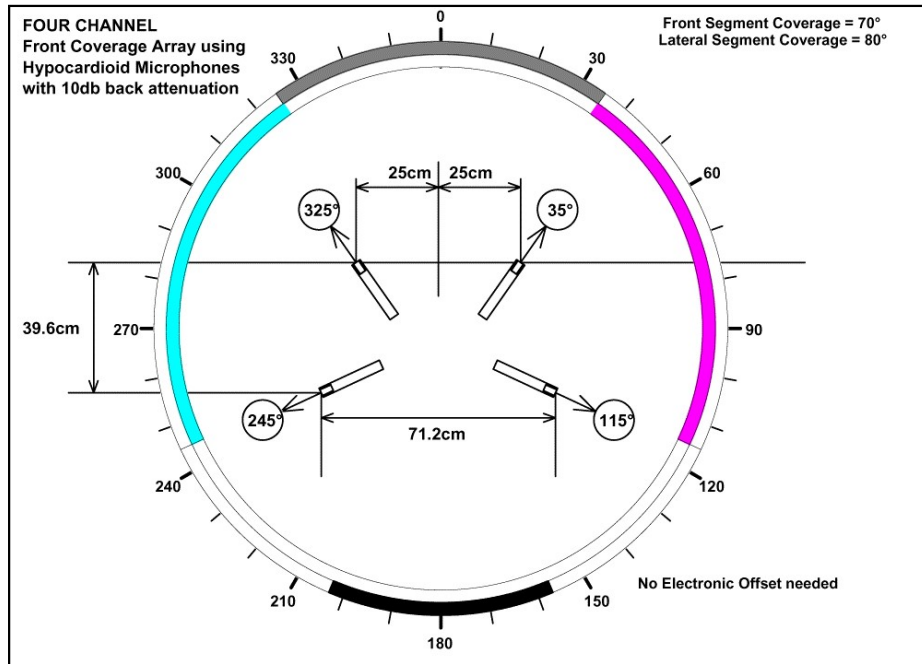


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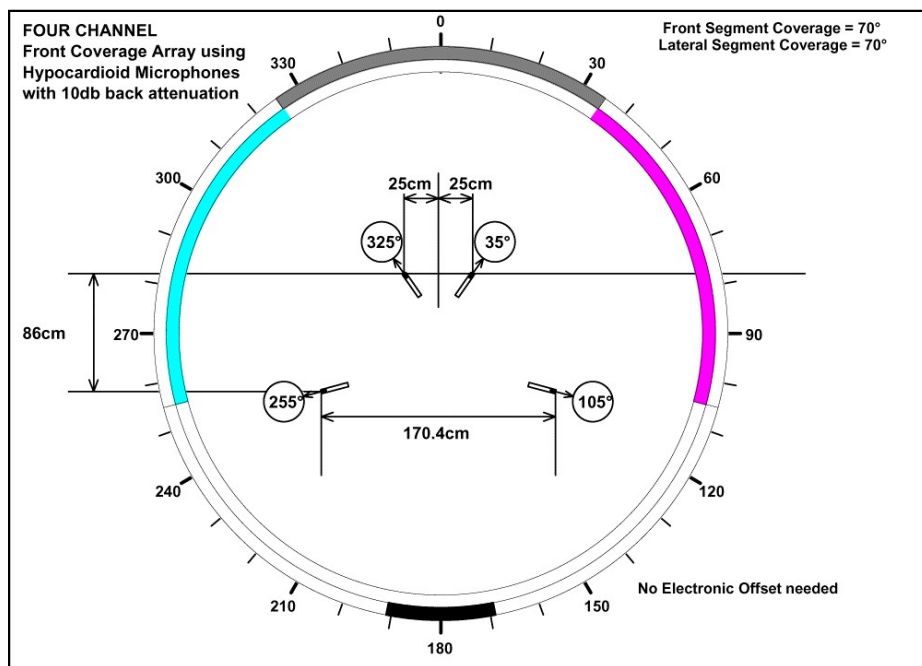


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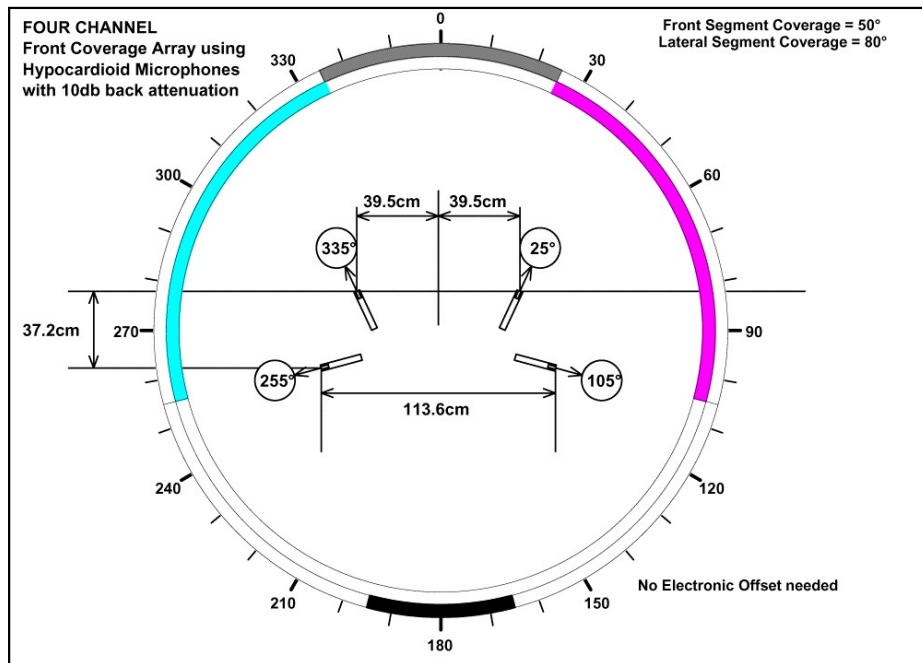


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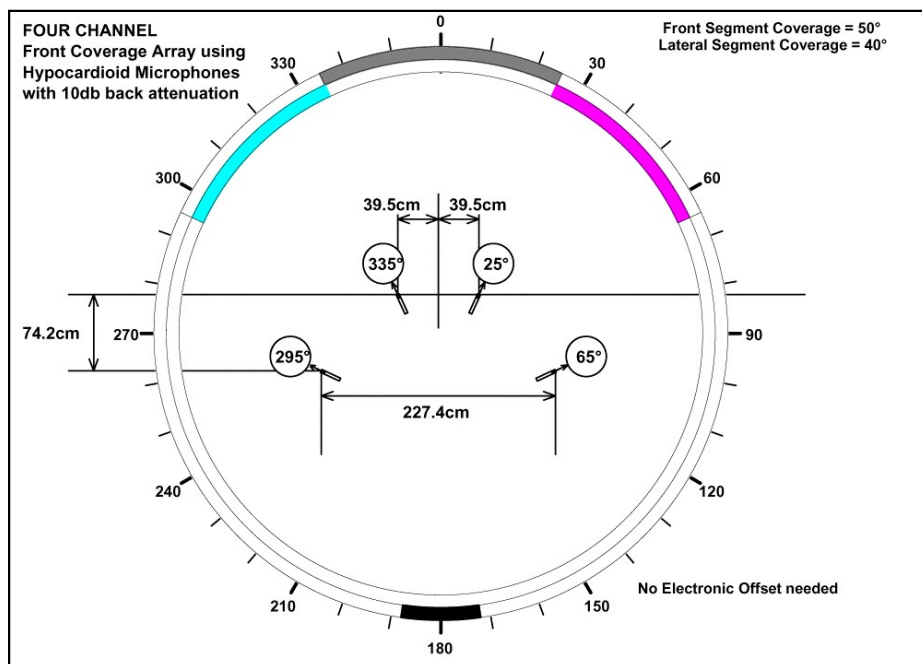


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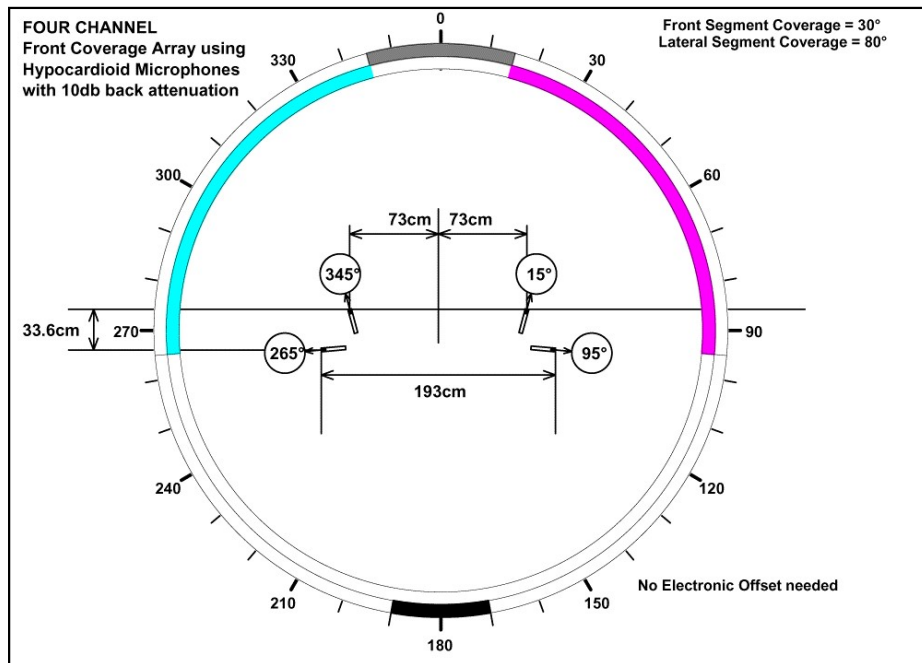


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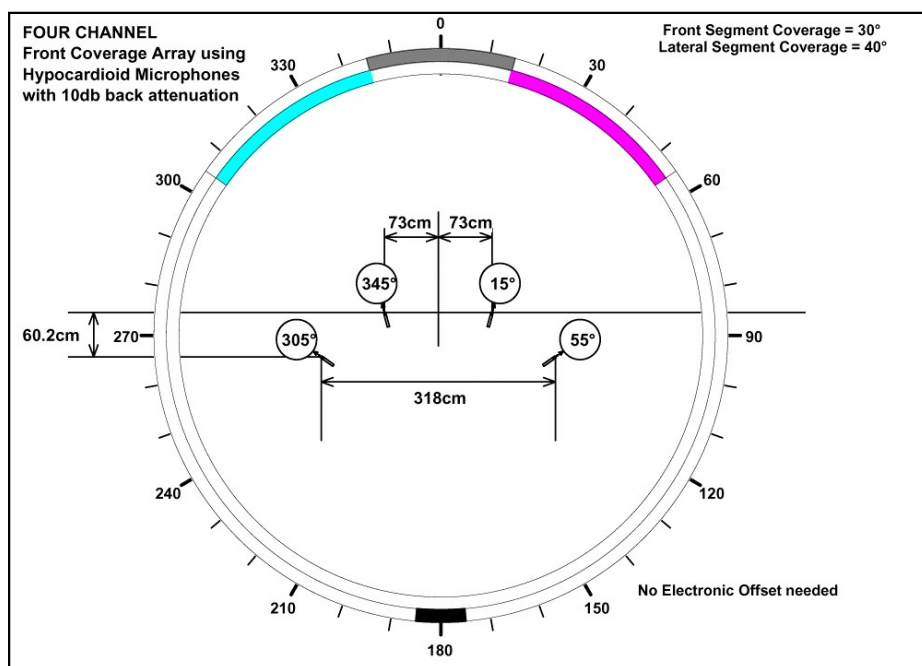


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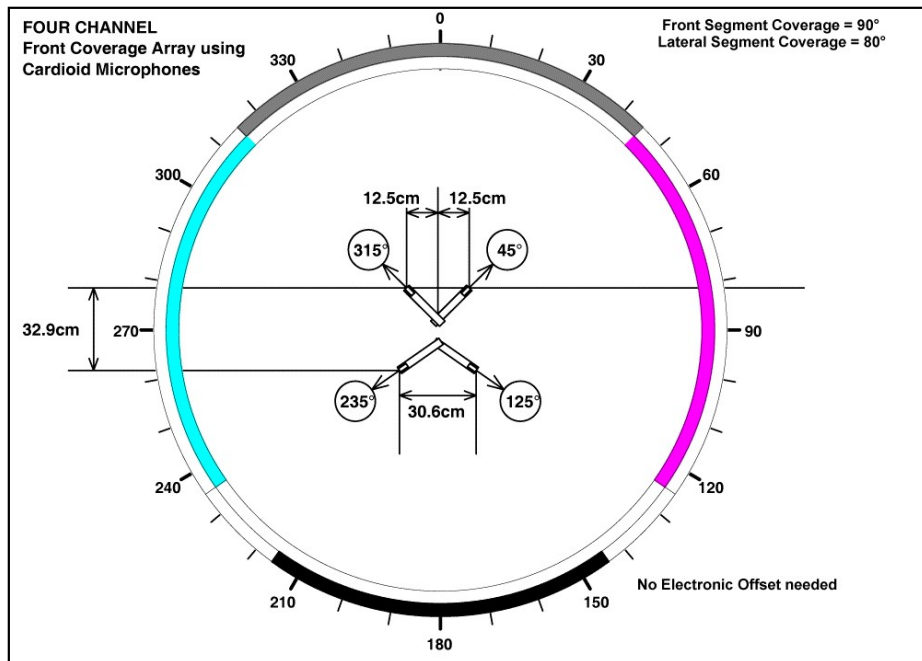


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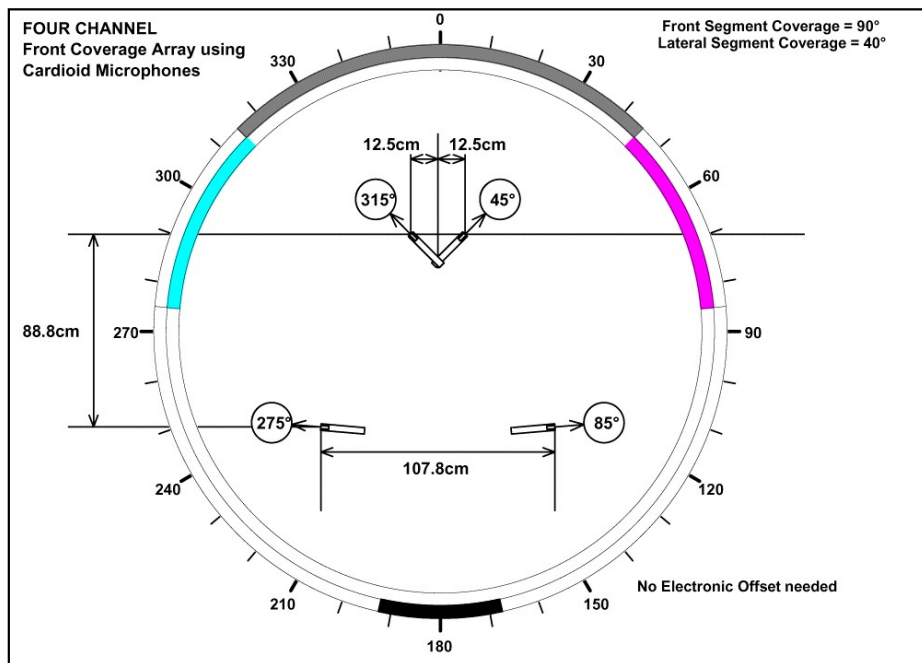


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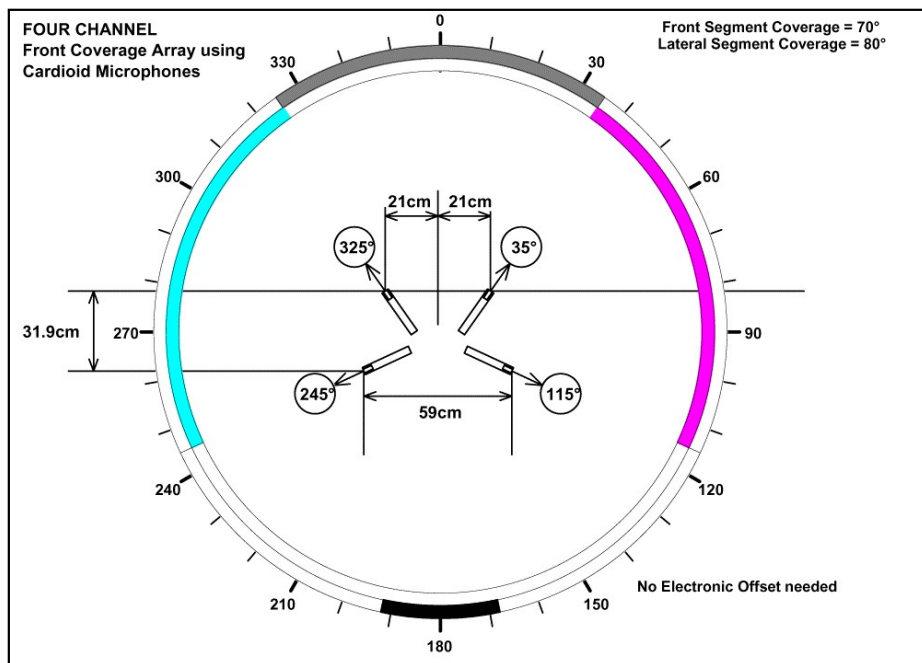


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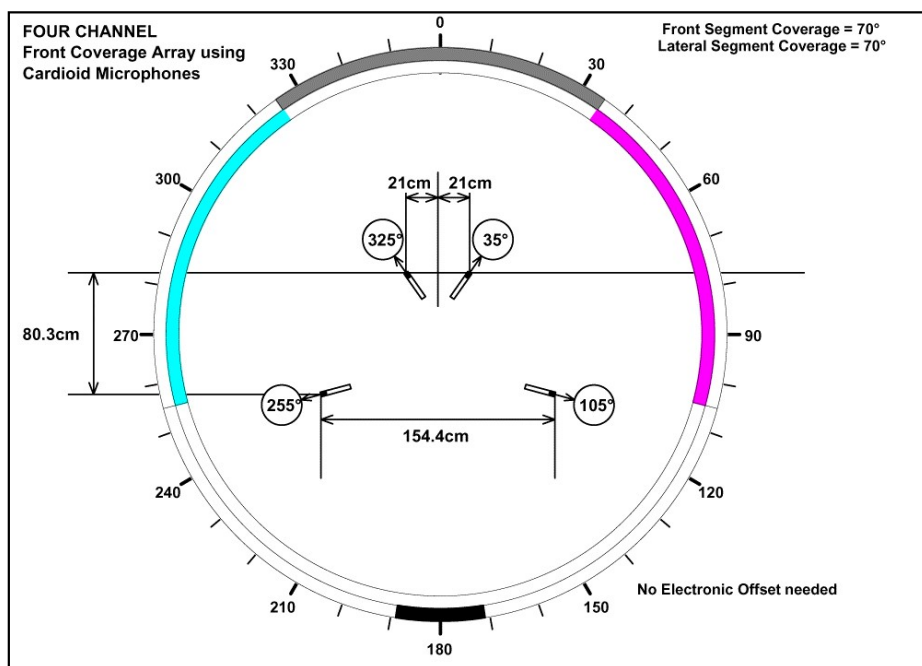


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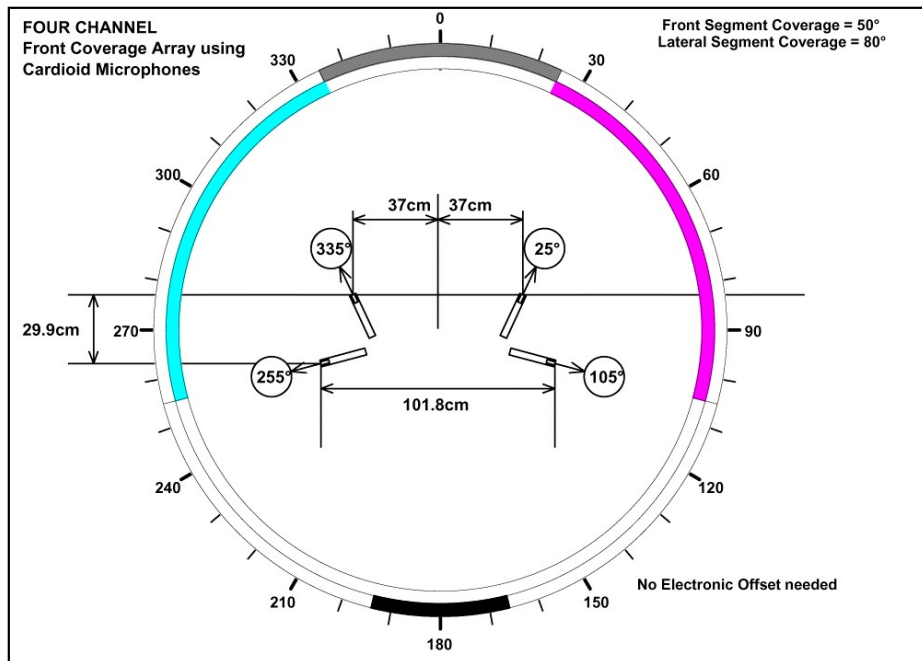


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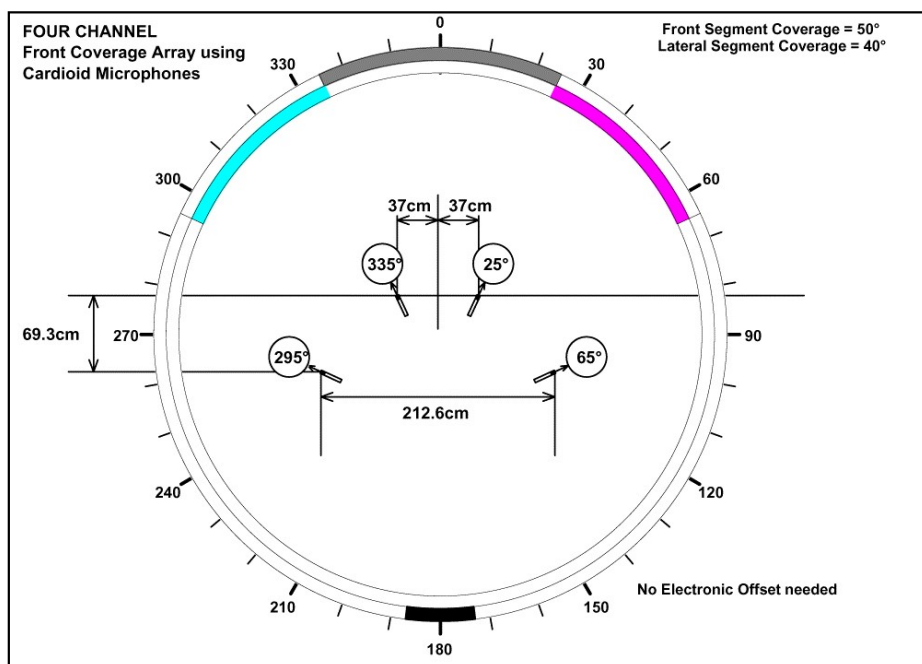


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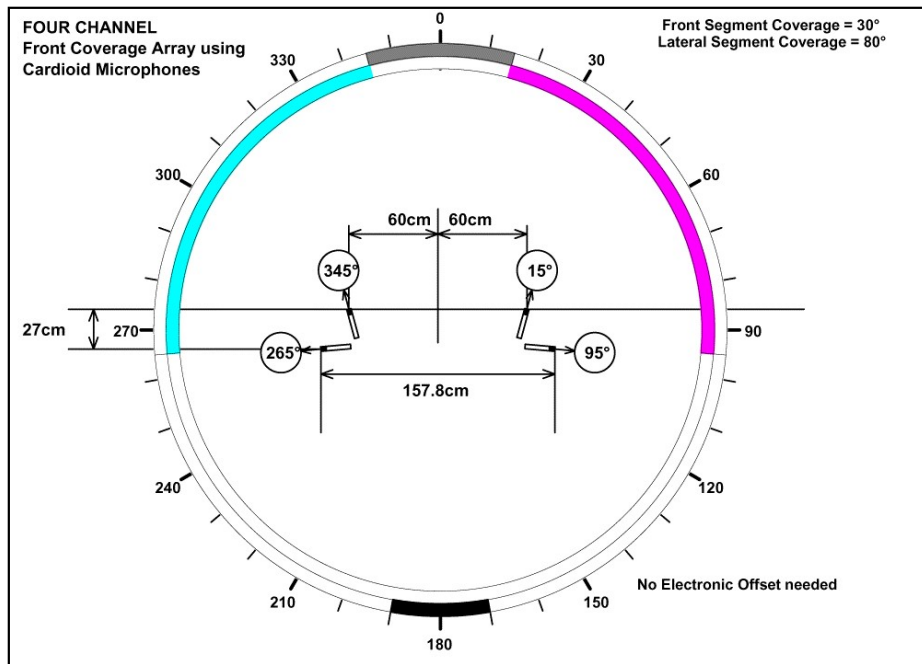


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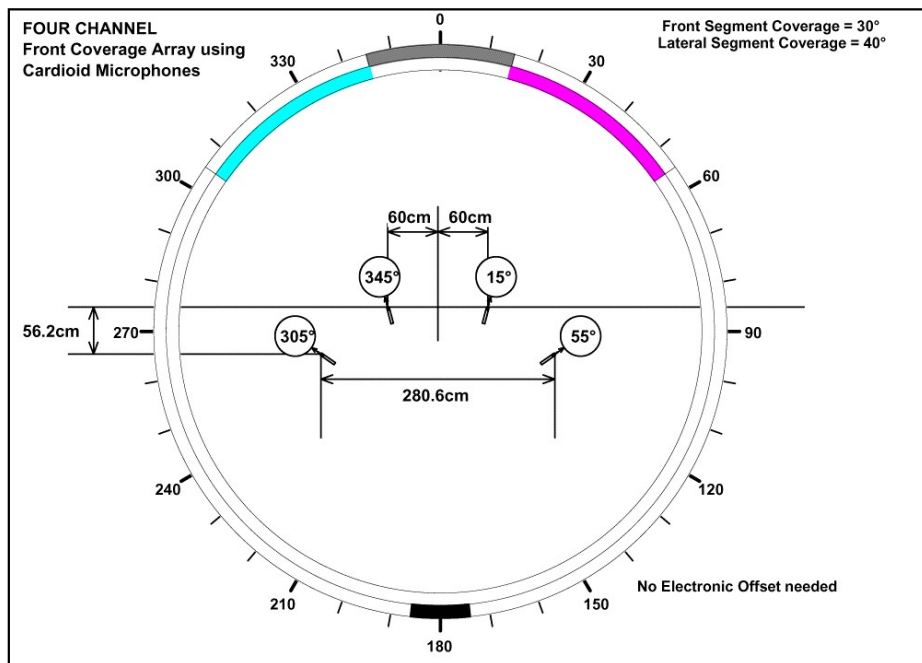


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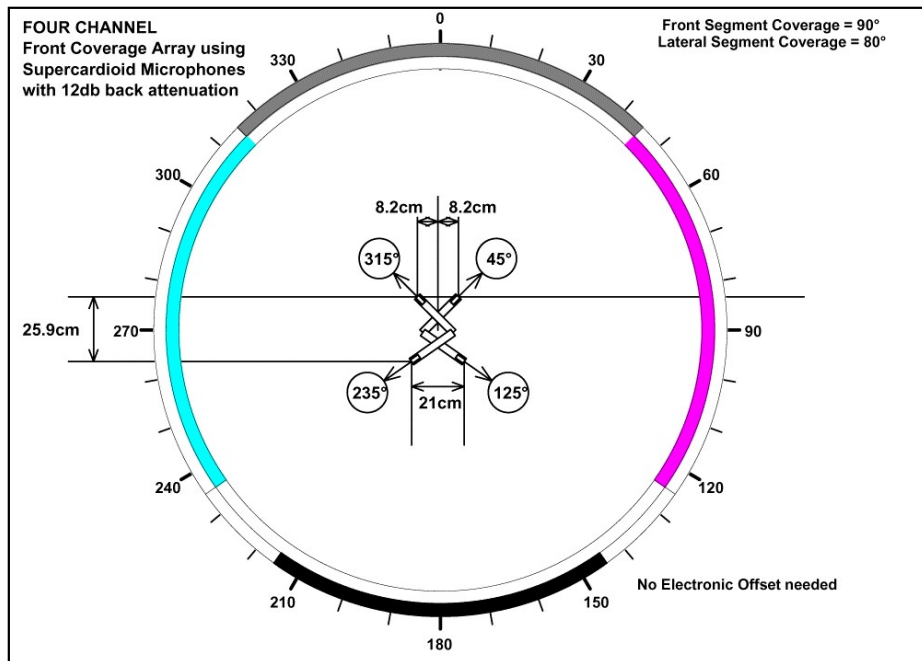


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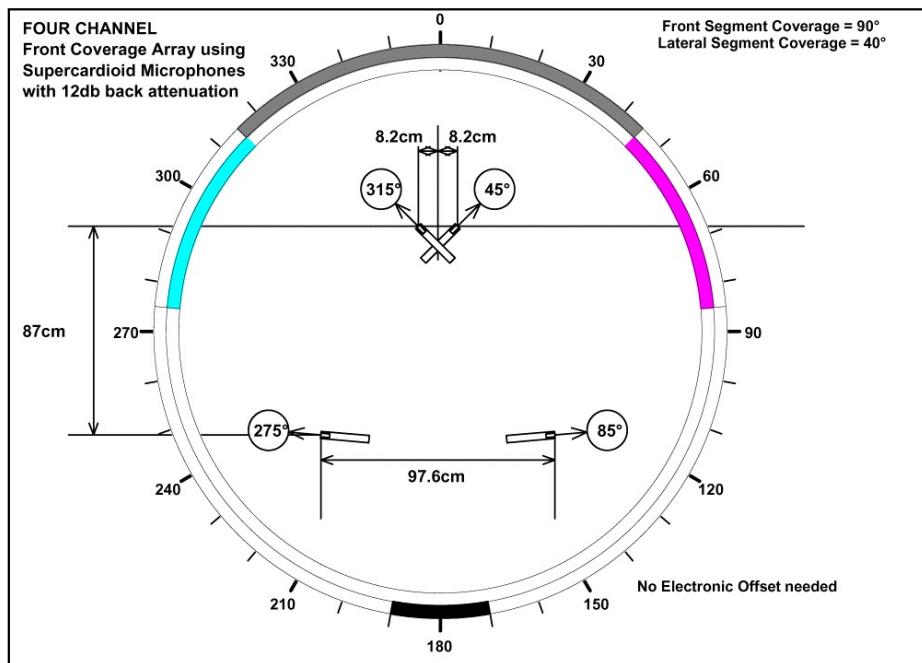


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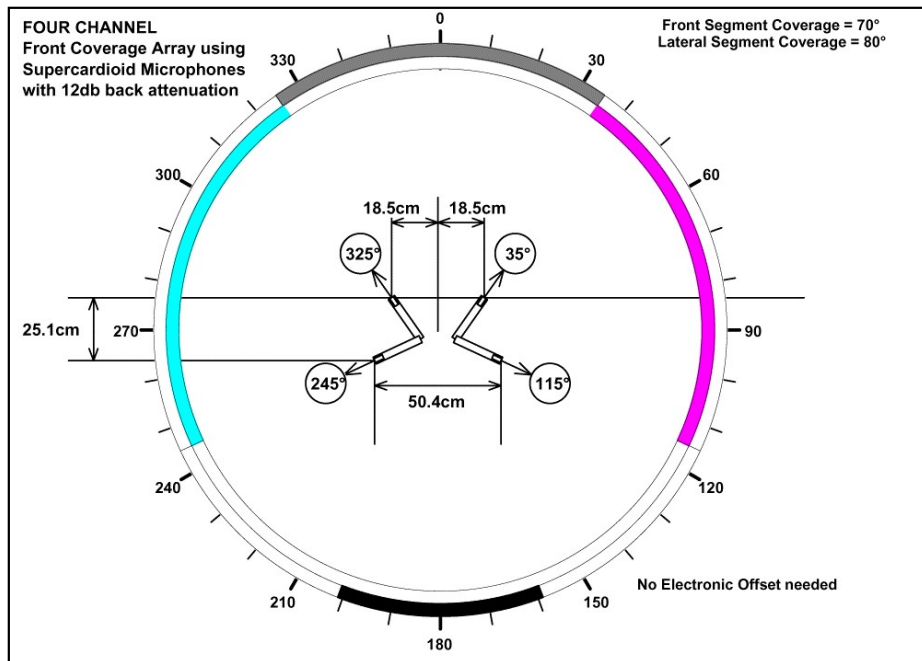


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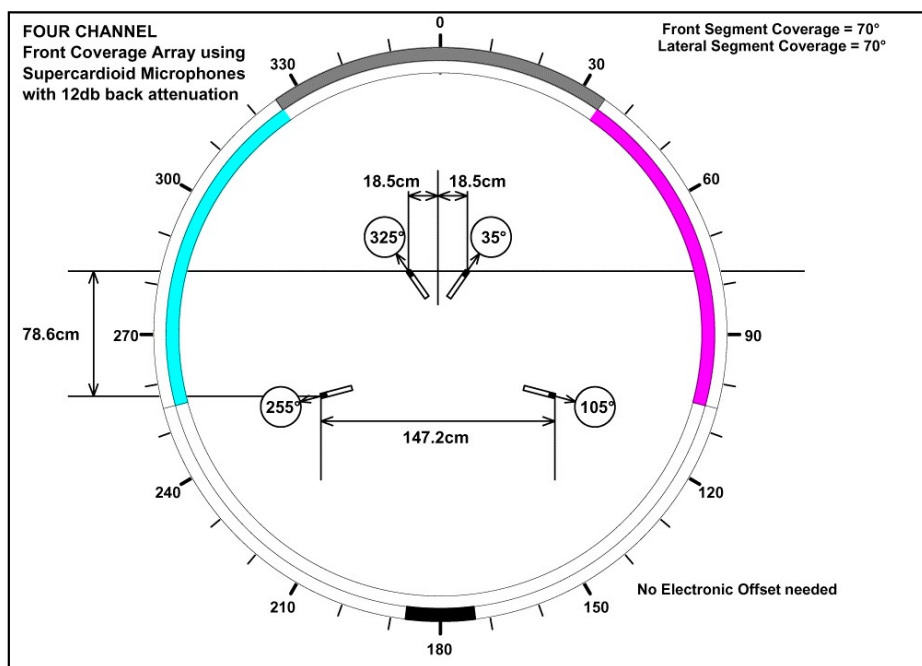


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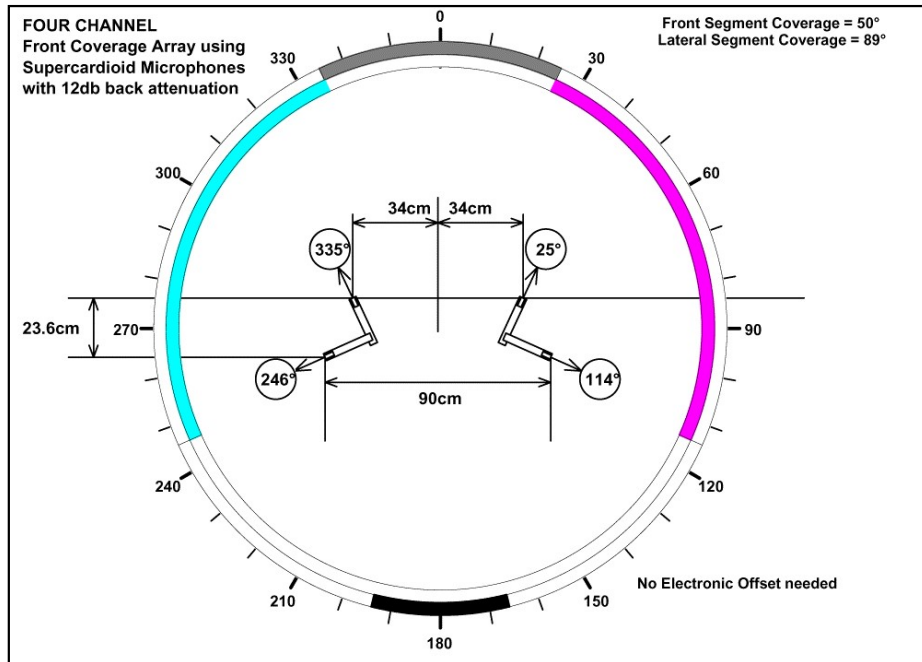


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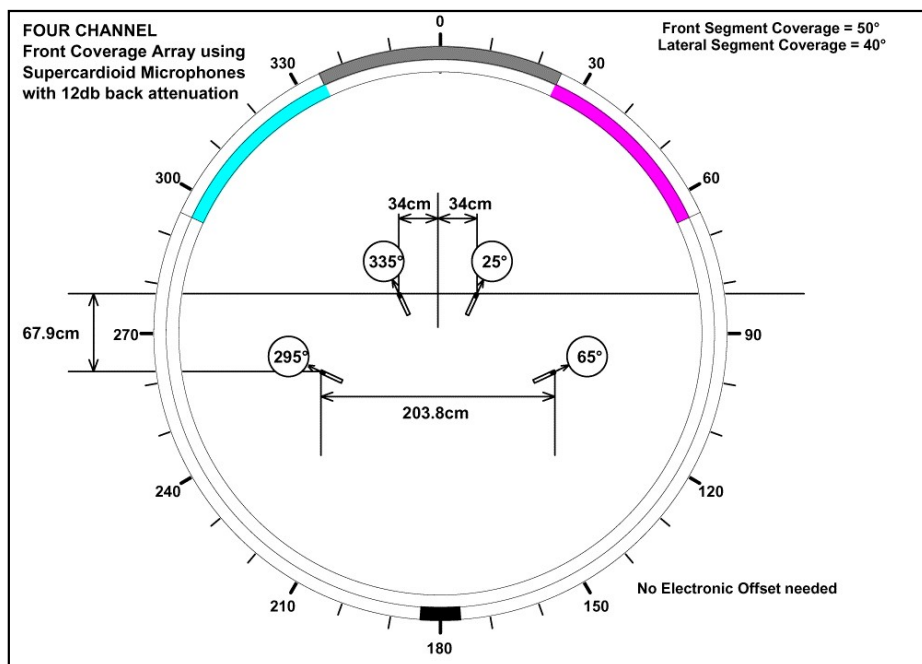


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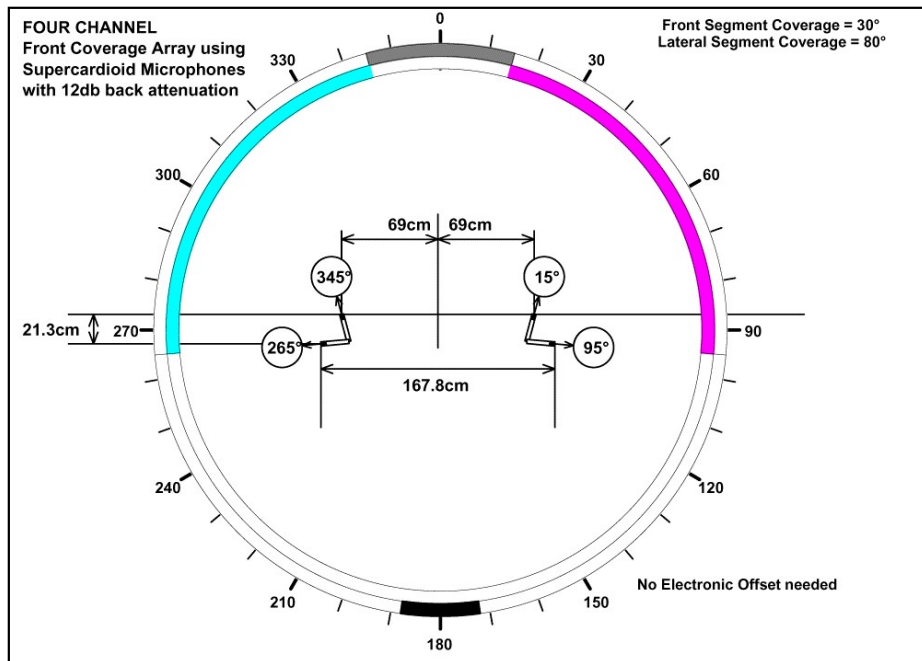


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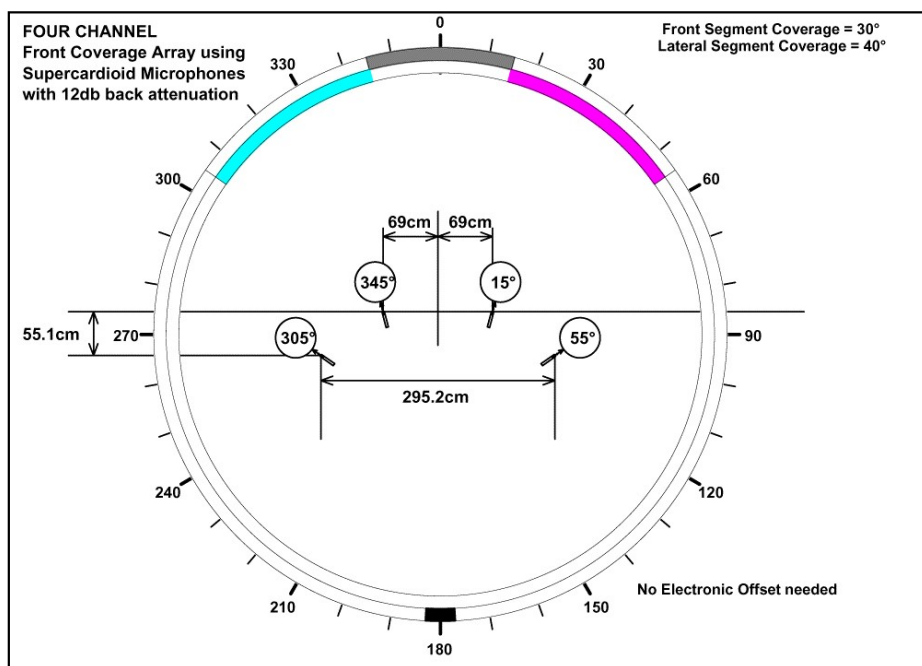


Figure 95