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MEETING THE CRITERIA- A MANUFACTURERS VIEWPOINT

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1. INTRODUCTION

The radio (or wireless) microphone was developed to replace the microphone cable with a radio link. This apparently straightforward task has, over the years been made progressively more difficult, as the number of radio microphones used together and the demands made on them have increased.

This paper considers in general terms some of the design requirements of a multichannel radio microphone system.

2. WHY A 'MULTICHANNEL RADIO MICROPHONE SYSTEM'

Broadcasters and film makers were initially the main users of radio microphones. Their application was for outside filming where the radio microphone use was usually limited to one or two units operating at a time. With more users, other applications were found and the numbers of radio microphones used together increased. In the UK, four spot frequencies existed for radio microphone users. These were:
174.1, 174.5, 174.8 and 175.0MHz. With only one or two radio microphones being used at one time, little frequency planning was required. But the four spot frequencies were not all suitable for simultaneous use at one site and so users began to encounter operating and practical problems which were not apparent on single units.

3. SYSTEM SPECIFICATION

The first requirement of any Multichannel Radio Microphone System is a frequency plan. This must allow a number of radio microphone channels to operate simultaneously as a set without mutual interference.

With separate transmitters, it is really the receivers that are combined into a system. As a minimum this should include the following:

The receivers should be housed in a single unit.
The receiver should be a diversity type.
The individual receivers and other component parts of the system should be modular.
The housing for the receivers should contain all the service functions such as power supply and antenna distribution.
The housing for the receivers and other modules should contain all the required power and signal interconnections.
A range of different capacity housings should be available.

Both hand held and pocket transmitter types should be usable in any combination.

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4. USERS AND THEIR REQUIREMENTS

Broadcasters

The two main broadcast applications for multichannel systems are in studios and in outside broadcast work. For the studios the size of the system is modest, 4-6 channels being typical, some housed in rack mounting frames but mostly in transportable case frames. 2 or more sets may need to operate together to increase the number of channels. Hand held and pocket transmitters used.
Requirement: highest audio quality, easily transportable.

For the Outside Broadcast work there is a similar system usage, some OB vans having rack mounting frames, but most systems being in transportable case frames. Hand held and pocket transmitters used.
Requirement: good operating range, easily transportable, highest audio quality,

Film makers

Not much demand for large multichannel sets but medium size 6-8 channel transportable systems are often used. Pocket transmitters used.
Requirement: long range, highest audio quality, easily transportable.

Theatres

Large multichannel sets used especially in modern musical productions such as Miss Saigon, Les Miserables, Phantom of the Opera. Fixed rack mounting systems, mainly pocket transmitters.
Requirement: 30+ channels, highest audio quality, large audio dynamic range.

Sound companies

Sound companies provide complete sound packages for events such as pop concerts. Mostly medium size 6-8 channel systems but 2 or more systems may need to operate together, rack mounting and transportable systems, mainly hand held transmitters
Requirement: highest audio quality, large audio dynamic range, rugged.

Conference centres

Mostly modest size 4-6 channel, some medium 6-8 channel systems but 2 or more systems may need to operate together. Transportable case frames, hand held and pocket transmitters used.
Requirement: good audio quality, simple to use, rugged.

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5. LEGAL CONSTRAINTS

5.1 Type Approval

All professional radio microphones used in the UK should be type approved by the Radiocommunications Agency (part of the DTI) after type testing to the MPT1350 specification [1].

For the design of a multichannel system a key part of this specification is the output power limit for the transmitters : 50mW e.r.p for a body worn device or 10mW e.r.p for a hand held.
The difference in these limits makes some allowance for the lower radiating efficiency of the body worn transmitter antenna, due to the human body absorbing much of the radiated RF field.

In a design worst case, both the hand held maximum and body worn minimum signal strengths need to be taken into account.

MPT1350 also specifies the maximum deviation allowed and the channel bandwidth, both of which are important parameters applicable to the overall design.

5.2 Frequency Allocation

In the UK frequency allocation is by the type of user rather than the type of use: broadcasters, theatres, and independent programme makers all having different frequency allocations. The broadcasters are in a special category because they have access to any unused TV channels in the broadcast spectrum in bands 4 and 5

When the DTI agreed to the allocation of radio microphone frequencies for theatre use (later extended to include other indoor fixed site users), Audio Engineering was asked to develop possible interleaving multichannel frequency sets. This work was used to assess the spectrum required to meet the combined projected needs of the theatre and independent users. Unfortunately, rather than allocate the suggested bands of spectrum, the allocations were only issued on a spot frequency basis. This was due more to the objections of the existing primary users of those frequency bands than for any technical reason. Although the spot frequencies issued were calculated to allow the simultaneous use of 26 theatre channels and 8 independent channels, this made only partial use of the original plan. The set shown (Table 1) is only one of four 8 channel sets designed to fit in an 8MHz band to maximise the spectrum utilisation between different users. This has meant that these UK frequency allocations are not as 'efficient' as they could be when single large multichannel systems are needed. Recently through the work of ASP [2] parts of TV Ch 69 have been licensed for radio microphone use. Learning from experience, some of this is now released as bands of spectrum rather than specified frequencies.

The theatre (or fixed indoor site) allocation is largely on a spot frequency basis.

The Independent programme makers allocation is only on a spot frequency basis.

Unless the frequency allocation in the UK is changed from spot frequencies to spectrum bands, the frequency plan of multichannel sets is not variable for non-broadcast users apart from those in TV Ch69. This restriction will potentially block the introduction of other plans for non broadcast users.

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8 Channel Theatre Radio Microphone Set With Intermodulation Product Table

FREQUENCY	A + B						A + B + C		
	3rd ORDER			5th ORDER			3rd ORDER		
	<150KHz	<100KHz	<50KHz	<125KHz	<100KHz	<50KHz	<100KHz	<75KHz	<50KHz
583.955	-	-	-	-	-	-	2	2	-
584.155	-	-	-	-	-	-	2	2	-
584.935	-	-	-		-	-	2	2	-
585.240	-	-	-	-	-	-	2	2	-
586.070	-	-	-	-	-	-	2	2	-
586.735	-	-	-	-	-	-	1	1	-
588.900	-	-	-	-	-	-	3	3	-
589.150	-	-	-	-	-	-	2	2	-
	Worst 3rd order...155KHz			Worst 5rd order...160KHz			Worst A+B - C...50KHz		

Table 1

6. INTERMODULATION

Intermodulation is the generation of unwanted spurious output by the interaction of two or more signals in a non linear device.

6.1 Transmitter Intermodulation

In a radio microphone transmitter the non linear device is usually the power output stage, which for reasons of efficiency is typically operating in class C. If two transmitters are physically close (<1.0MHz),they will interact producing a series of spurious signals (Fig 1). However it is only those which are close to the original transmitter frequencies that will be a problem. These signals take the form :

$$2f_1\text{-}f_2\ ,\ 2f_2\text{-}f_1\ ,\ 3f_1\text{-}2f_2\ ,\ 3f_2\text{-}2f_1$$

Substituting actual numbers will make the mechanism clearer:

If f_1=100MHz and f_2=101MHz:

$$2f_1\text{-}f_2 = 99\text{MHz}\ ,\ 2f_2\text{-}f_1 = 102\text{MHz}, 3f_1\text{-}2f_2 = 98\text{MHz}\ ,\ 3f_2\text{-}2f_1 = 103\text{MHz}$$

These intermodulation products are known as 2 tone or A+B type.It can be seen that the intermodulation products occur at intervals equal to the frequency difference of the transmitters. The pair of spurious signals nearest the transmitter carriers are 3rd order (from the sum of the order of the terms): $2f_1 - 1f_2$. The next pair out are 5th order: $3f_1\text{-}2f_2$. Higher order products are not usually produced even under extreme operating conditions.

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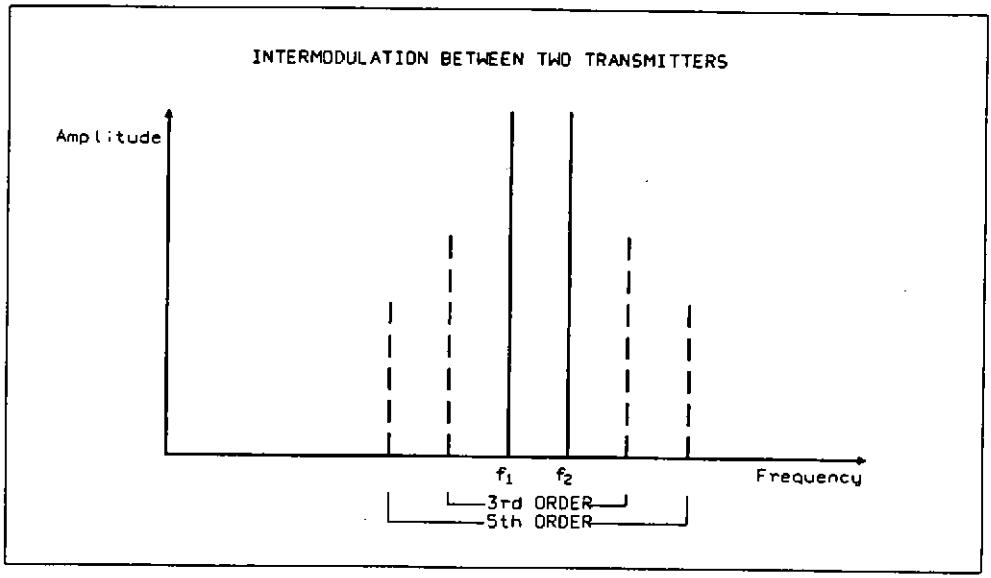
If the two close transmitters are also similar in frequency (within 1MHz), the intermodulation products will be of appreciable amplitude. Also because these intermodulation products are produced from harmonics of the original modulated signals the deviation on them will be appreciably higher. These transmitter generated intermodulation signals should not be ignored.



Another 3rd order spurious intermodulation signal will be generated when a third transmitter is introduced. This is known as a 3 tone or A+B - C type and takes the form :

$f_1+f_2-f_3=f_x$ where f_x is a fourth channel.

In practice this type of intermodulation is not normally a transmitter problem, due to the difficulty in getting three transmitters physically very close and the necessarily greater frequency separation of any third transmitter.

6.2 Receiver Intermodulation

For a single receiver it is the linearity of the input stage(s) and the large signal handling capability of the first mixer that determines the level of intermodulation products generated within the receiver. A high Q input filter ideally protecting the receiver from other unwanted signals. In a multichannel system the input stage is usually part of the antenna distribution circuit or even in a masthead pre-amp. Here it is subject to the greatest conflict of design goals. It must, at the same time, be low noise, high gain and linear to relatively high input levels, all without the protection of a high Q filter. However the input filter bandwidth should be tightly tailored to only

accept the wanted radio microphone transmitter signals (especially needed when operating near a used TV channel). Although it is possible to produce both A+B and A+B - C intermodulation products within the receiving system in practice it is mostly the A+B - C type. This intermodulation will normally occur only under strong input overload conditions

7. FREQUENCY PLANNING

The generation of a frequency plan is carried out after the basic parameters of the system have been established. These include: deviation levels, minimum channel spacing, receiver selectivity and receiver system 3rd order intercept point. From these figures the acceptable limits for the intermodulation products can be deduced. The limits are then used to calculate the optimum channel spacing and the set size.

8. CONCLUSION

Multichannel radio microphone systems have been in use for more than 10 years. Even after this length of time it is only the theatre users who regularly need more than one of the 6 or 8 channel systems currently available.

Manufacturers of larger, more complex and more expensive systems may well find a diminishing market for such a product in the current economic climate. It is high audio quality and the general reliability of the system under adverse working condition that most users require. If either of these qualities are compomised by the introduction of larger frequency sets within an 8MHz band, it will restrict the user base still further.

For a non broadcast user in the UK any multichannel radio microphone system with a new frequency plan will have to wait for a change in the regulations before it can legally be used.

9. REFERENCES

[1] MPT 1350 PERFORMANCE SPECIFICATION Radio microphone equipment requiring the issue of a licence for use in the VHF and UHF bands.

[2] ASP Frequency Management Ltd Edgecott House, Lawn Hill, Edgecott, Aylesbury HP18 0QW.