Why does the audio carried by FM signals only go up to 15KHz?

Application Notes-065-V1.0

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1、Interpretation of Standards

Relevant international standards such as ITU-R BS.450, BS.640 and China's "Technical Specifications for FM Broadcasting" clearly stipulate:

– Audio passband: 50 Hz–15 kHz (±1 dB)

– Attenuation above 15 kHz ≥ 40 dB

The standard limits the frequency of the audio signal carried by FM to 15 kHz to prevent adjacent channel interference, reduce noise, and thus ensure global compatibility. If the transmitting end emits energy at frequencies above 15 kHz, it will generally be judged as an "excessive emission".

2、Reasons for the 15KHz Limit in Standards

In FM broadcasting, limiting the upper frequency of the audio signal to 15 kHz is mainly due to three reasons:

1. Human Auditory Range and Subjective Perception

• The human ear is very insensitive to sounds above 15 kHz. Adults can usually only hear sounds below 16–17 kHz, and retaining higher frequency bands contributes almost nothing to the "listening experience".

• The energy of overtones in music attenuates rapidly above 15 kHz. Retaining them improves the timbre minimally but brings additional noise and distortion.

2. Economic Trade-off between Bandwidth and Signal-to-Noise Ratio

• The channel spacing for FM is usually 200 kHz (North America) or 100 kHz (some European countries).

• Carson's bandwidth formula: $B \approx 2(\Delta f + fm)$, where Δf is the maximum frequency deviation (75 kHz) and fm is the highest audio frequency.

– If fm = 15 kHz → B ≈ 2(75 k + 15 k) = 180 kHz, which just fits within the 200 kHz channel.

– If fm is increased to 20 kHz → B ≈ 190 kHz, the edge margin is too small, and the risk of adjacent channel interference increases significantly.

• A higher fm will also cause the noise power (proportional to fm^2) to rise significantly, reducing the signal-to-noise ratio.

Therefore, overall, limiting to 15 kHz achieves the optimal compromise between "audible bandwidth" and "system noise".

3. Historical Standards and Compatibility

• The FM stereo standard formulated in 1961 directly adopted the 15 kHz upper limit of early mono FM, so that global receivers can be compatible without modification.

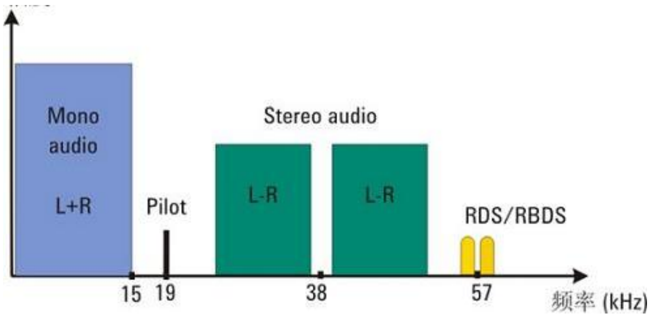
• A large number of derivative systems such as TV sound, wireless microphones, and walkie-talkies are also designed accordingly, forming an industrial inertia.

Therefore, setting the upper limit of audio in FM broadcasting at 15 kHz is a comprehensive engineering decision that takes into account "human auditory perception, bandwidth utilization, signal-to-noise ratio, and historical compatibility".

For this reason, the pre-emphasis curves all go up to 15 kHz.

3.Design Architecture Limitations of Modern Instruments

Let's look at the spectrum diagram of MPX as follows:



Benefiting from the development of modern electronic technology, modern instruments can achieve more flexible upgrades and compatibility through more software engineering. For example, one instrument can be compatible with multiple standards. However, instruments dominated by software engineering also have some defects. After all, "you can't have both fish and bear's paw".

Modern instruments more or less adopt software technology, such as software filtering. When we need to decode MPX, we need to use software filtering for processing. In order to obtain L and R signals well, we need to perform low-pass filtering. Considering the 19 kHz pilot signal, we need to make a trade-off between 15 kHz and 19 kHz for the filter cutoff frequency (considering the influence of the filter curve). RWC2500A chooses 16 kHz, which is the fundamental reason why our LPF setting only goes up to 16 kHz. This is not only the case for RWC2500A, but also for ETL.

In fact, the fundamental reason is that the entire standard system basically only considers up to 15 kHz, so the pilot frequency is set at 19 kHz.

4、Analysis of Two Core Indicators

Based on the above analysis, there are two core indicators to discuss:

1. Frequency Response

The frequency response can reflect the performance when tested up to 15 kHz according to the standard requirements, so 2500A currently displays the results according to 15 kHz.

It is worth noting that studio applications are relatively special. Studios not only need to meet the requirements of FM broadcast transmission, but also consider various other radio and television applications, such as DAB/DRM or CDR and other digital broadcast applications, which require supporting an audio range up to 20 kHz. Such tests need to be compatible up to 20 kHz.

2. THD Test

THD essentially detects the harmonic components of the signal, with the lowest being the 2nd harmonic. Taking our aforementioned LPF setting of 16 kHz as an example, the supported baseband audio frequency is 8 kHz. In other words, for baseband audio higher than 8 kHz, the harmonic components will not be calculated, so all THD values are theoretically 0.

This is not only the case for RWC2500A, but also for ETL.

5、Summary

Modern broadcast testing instruments such as R&S ETL and RWC2500A mostly adopt software technology as much as possible on the basis of the basic hardware architecture to achieve better standard compatibility and scalability, with powerful functions, flexible display, and convenient data import and export. Such instruments are different from transistor instruments decades ago, and many filters are based on software algorithms.

According to the standard requirements and the needs of actual test instrument development, for FM stereo testing, achieving frequency response testing up to 15 kHz meets the standard requirements. More importantly, the industry's test benchmark instrument FMAB from decades ago has almost disappeared. R&S's ETL, which replaced FMAB, has also been discontinued. Even if it were not discontinued, ETL is not as good as FMAB in some aspects, especially in terms of filtering characteristics, harmonic characteristics, and flatness. RWC2500A's performance indicators are comparable to ETL, and it also solves the problem that ETL does not support AM real-time demodulation testing. More importantly, RWC2500A solves the problem of extremely complex operation interfaces and processes of FMAB and ETL. In this sense, RWC2500A is a perfect continuation of FMAB and ETL, continuing to safeguard the quality of broadcast transmission.