IAC-06-A4.1.01

UPDATING THE SAN MARINO SCALE

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ABSTRACT

The issue of transmitting deliberate messages from Earth into interstellar space remains controversial. At last year's International Astronautical Congress in Fukuoka, we introduced the San Marino Scale, a new analytical tool for assessing transmission risk. We engaged in a stimulating dialog at that Conference and elsewhere, and have received and analyzed feedback generated by our earlier paper. We are now in a position to recommend specific improvements to the scale we proposed for quantifying terrestrial transmissions. Our intent is to make it better reflect the detectability and potential impact of recent and proposed messages beamed from Earth (or even of a time capsule prepared as a message for future generations). We believe the changes proposed herein strengthen the San Marino Scale as an analytical tool, and bring us closer to its eventual adoption.

INTRODUCTION

While SETI, the Search for Extra-Terrestrial Intelligence, is a widely accepted science, the reciprocal activity sometimes called METI, Messaging to Extra-Terrestrial Intelligence, remains a controversial area, and receives much discussion and debate within the SETI community. The authors of the San Marino Scale **[1, 2]** last year proposed a tool to give such discussions a modest analytical basis. We emphasized that it was a work in progress, and solicited feedback and suggestions from the attendees at various conferences at which the proposed scale was discussed. We now seek to update the San Marino Scale previously introduced, based upon that feedback, and subsequent email discussions among members of the IAA SETI Permanent Study Group.

THE PARAMETRIC TERM 'I'

In its first iteration, signal intensity, the parametric (quantifiable) term of the San Marino Scale (referred to by the literal 'I') was referenced to the Earth's microwave footprint, as follows:

"I is a logarithmic measure to the base 10 of signal strength or intensity, relative to the Earth's background radiation intensity…"

We now suggest that for all practical purposes, it is the Sun's background radiation intensity, and not Earth's, that limits detectability of our planet's microwave signals. We deem it unlikely that a distant SETI antenna will enable ETI to separate terrestrial microwave radiation from that of our Sun.

Consider a transmission from Earth to even the nearest star. For convenience in computation, let us set the transmission distance at 1 parsec (pc) [it is actually a little greater than this]. The pc is defined as the distance at which an object displays a parallax of 1 second of arc across a baseline of 1 astronomical unit (which is, of course, the radius of the Earth's orbit). By symmetry, the Earth, as viewed from that star, will thus appear to be separated from the sun by an angular distance on the order of one arc sec.

1 arc second equates to just under 5 E-06 radians. Thus, to resolve over interstellar distances a signal from Earth, independent of radiation from our Sun, a receive antenna must have a beamwidth of less than 5 E-06 radians.

For a single parabolic antenna, the receiver 3 dB beamwidth, in radians, equals roughly wavelength divided by diameter [with the two measured in like units]. Given a terrestrial microwave signal at, say, the hydrogen line (wavelength equal to 21 cm), the required receive antenna diameter to achieve a beamwidth of 5 micro-radians would be about 45 km. Thus, to resolve Earth and Sun over interstellar distances at 21 cm, it would take a single parabolic reflector at least 45 km in diameter, or a properly phased array of smaller antennas with equivalent capture area -- in other words, the equivalent of more than 2,000 Square Kilometer Arrays, all working in concert.

In an excellent article dealing with the likelihood of ETI detecting terrestrial television broadcasts, Scheffer **[3]** considers two receive antennas, a "small" one of 30 km diameter, and a "large" one spanning 1,000 km. He computes, for the former, a range of 280 LY for detection of terrestrial UHF TV carriers. However, in his calculations Scheffer assumes an extraterrestrial receiver whose sensitivity is limited only by the 2.7 Kelvin cosmic microwave background. As we have just shown, a 30 km aperture is insufficient to eliminate solar radiation from its beamwidth; thus, antenna noise temperature will significantly exceed the cosmic microwave background, and detection range will be correspondingly reduced. This underscores our assertion that the Sun is the limiting factor in practical detection of Earth's microwave leakage emissions.

What of the "large" antenna Scheffer suggests? Clearly, a 1000 km aperture could easily resolve the Earth and the Sun. Such an array could, perhaps, be built on a moon. (Pointing its vanishingly narrow beamwidth with reasonable accuracy would probably require steering that moon in its orbit, an engineering challenge which would likely make even the most advanced ETI shudder.) However, it is true that, in the case of an array with a capture area of a million SKAs, over interstellar distances, the Sun's noise is no longer a limiting factor.

But, Earth has yet to build a *single* SKA, much less a million such instruments. We will certainly not here attempt to limit the technological capacity of extraterrestrial civilizations. We concede that interferometric techniques can indeed be used to null out the glare of a star, when attempting to image individual planets. These techniques, which have been demonstrated in the optical spectrum, show promise even at microwave frequencies, though wavelengths (and hence antenna size) are five or six orders of magnitude greater. Space-based VLBI techniques **[4]** are a demonstrated possibility. They are unlikely to prove particularly useful in the search phase, however, being more practical once the presence and location of a target planet (in this case, Earth) are already known to, or at least suspected by, the extraterrestrial astronomers. For SETI, it makes more sense to employ antenna beamwidths sufficient to encompass an entire solar system. In addition, the design and construction of even Scheffer's proposed "small" array are, to say the least, daunting. And, as the distance to the neighboring star increases, the angular separation between Sun and Earth becomes vanishingly small. We thus conclude that, in the case of ETI's own SETI programs, it is unlikely that any signal will be detected from Earth, absent a dominant solar background radiation component.

It is true that at certain times, in certain directions, and at certain frequencies, the microwave emissions from Earth caused by our technology can exceed those of the Sun by a million-fold or more. However, these terrestrial emissions are highly intermittent, exceedingly directional, and scattered across the spectrum. We are inclined to classify such powerful emissions as inadvertent METI signals. The Sun's microwave flux, on the other hand, is constant and isotropic. Thus, we suggest, the backdrop against which terrestrial signals must be evaluated is not Earth's modest 290 K thermal profile, nor even the average intensity of artificial terrestrial microwave emissions, but more properly the interference generated by a 5800 K thermal black body: our own Sun.

Given these considerations, we now propose to modify our definition of the parametric term 'I', as follows:

"I is a logarithmic measure to the base 10 of signal strength or intensity, relative to the Sun's background radiation intensity, measured in the same frequency range as the terrestrial transmission in question, and over a bandwidth equivalent to the total modulation bandwidth of the transmitted signal, or the detector bandwidth of the receiver intercepting it."

Table 1 below, a modification of Table 1 in our Fukuoka paper, reflects this change.

Intensity of Transmission	**Value of I**
$\geq$ 100,000 * I_{sol}	5
~ 10,000 * I_{sol}	4
~ 1,000 * I_{sol}	3
~ 100 * I_{sol}	2
~ 10 * I_{sol}	1
Solar flux intensity at the frequency of the transmission, over detection bandwidth consistent with the signal (~I_{sol})	0

Table 1: Revised I term

THE CATEGORICAL TERM ‘C’

Electromagnetic emissions from Earth, or anywhere else, can be highly directional (beamed or targeted), omnidirectional, or somewhere in between, as a function of transmit antenna gain. In categorizing the character of a transmission, the term ‘C’ as originally introduced made distinctions between directional and omnidirectional signals. We now believe those distinctions to be moot, in that directionality is already encompassed in the ‘I’ term.

The intensity term ‘I’ is derived from the effective isotropic radiated power (EIRP) of the transmission in question. EIRP is in turn a product of transmitter power and antenna gain. But antenna gain and directionality are inexorably linked. That is, a high gain antenna achieves its gain by focusing photons; high directionality inevitably results. Similarly, an omnidirectional antenna will, by definition, exhibit low gain. Thus, the directional character of a transmission has already been encompassed in quantifying its intensity.

To include directional characteristics in the determination of the categorical term ‘C’ will, in effect, give them double weighting. Thus, we now recommend that all references to directionality be omitted from the ‘C’ term, while retaining considerations of intentionality and information content.

Table 2 below, a modification of Table 2 in our Fukuoka paper, reflects this change.

Character of Transmission	Value of C
Reply to an extraterrestrial signal or message (if they are not yet aware of us!)	5
Continuous, broadband transmission of a message to ETI	4
Special signal targeting a specific star or stars, at a preselected time, in order to draw attention of ET astronomers	3
Sustained, untargeted message with the intention to reach ETI (e.g., Evpatoria)	2
A beacon without any message (e.g., planetary radar)	1

Table 2: Revised C term

MIXING UNITS

At the Fukuoka meeting, interesting questions were raised from the audience about the validity of deriving a quantitative criterion measure by summing parametric and non-parametric terms. It was noted that, while the Intensity term was clearly quantifiable, the contributions to detectability (and hence impact) of a signal’s nature clearly were not.

While we concede that there is no analytical basis for quantifying the potential impact of a signal based upon the characteristics listed in Table 2, we maintain that the considerations listed are at least ordinal. That is, a radar beacon lacking message content will clearly reveal to our interstellar neighbors less about our civilization than would a sustained message transmission. Similarly, the other categories for the ‘C’ term are ranked in terms of increasing information content, duration, detectability, or societal impact. Thus, we maintain that the rankings implied in the ‘C’ term are ordinally significant, as is ‘Q’ in the Rio Scale **[5]**, from which the San Marino Scale is a descendant. If not truly quantifiable, “C’ still has ordinal meaning in the context of the overall San Marino Scale (which is, after all, itself subjective, ordinal, and non-parametric).

STRUCTURE

Despite the minor changes suggested above, the San Marino Index remains as originally proposed, and is mathematically defined as:

SMI = I + C **[Equation 1]**

where **SMI** is the numeric San Marino Index, on an integer scale of 1 to 10,

I is a logarithmic measure to the base 10 of signal strength or intensity, now relative to the Sun’s radiation intensity (think “Bels over background”), with a maximum value of 5,

and **C** still represents the characteristics of the transmission, with regard to information content, intentions, and duration (but no longer directionality).

The overall San Marino Index remains a qualitative tool for assessing relative transmission risk.

CONSIDERING TIME CAPSULES

METI (Messaging to ETI) includes not only electromagnetic emissions, but also such artifacts as the plaques on the Pioneer probes and the records on the Voyager interplanetary spacecraft. They are en route to possible alien civilizations. There are similar plaques on some long-living satellites as well (e.g. LAGEOS) which can be considered as messages to future generations of humankind. Who knows who will discover these physical messages: our descendants, or representatives of ETI?

It is only a small logical step from such messages to existing "time capsules" here on Earth, intended as messages to future generations. An early example (circa 1940) is the "Crypt of Civilization" at Oglethorpe University, Atlanta, GA, USA. **[6]**

It is our opinion is that such time capsules face problems very similar to the case of Active SETI: who decides what the message should contain, who is responsible, what kind of time capsule should be considered a serious message, and what only a joke of an amateur? We therefore respectfully suggest that something akin to the San Marino Scale could well be applied to quantifying the potential impact of such Messages to the Future.

CONCLUSIONS

The proposed San Marino Scale remains a work in progress. It has still not been adopted by any regulatory or advisory body. Doubtless, many future changes will be proposed, and some adopted, before this tool is ready for prime time. In the interim, we believe the two changes proposed herein (referencing intensity to solar radiation, and eliminating directionality as a consideration for the categorical term) strengthen the San Marino Scale as an analytical tool, and bring us closer to its eventual adoption.

REFERENCES

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